Power Mac G5 Developer Note

(Legacy)

Developer

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Introduction to Power Mac G5 Developer Note

Important: This document may not represent best practices for current development. Links to downloads and other resources may no longer be valid.

This developer note describes the 64-bit Power Mac G5. The note provides information about the internal design of the computer, its input-output and expansion capabilities, and issues affecting compatibility.

This developer note is intended to help hardware and software developers design products that are compatible with the Macintosh products described here. If you are not already familiar with Macintosh computers or if you would simply like additional technical information, refer to Appendix A, Supplemental Reference Documents, (page 64) for additional information.

Organization of This Document

The information is arranged in four chapters and two appendixes:

- Chapter 1, Overview to the Power Mac G5, (page 8) gives a summary of the features of the Power Mac G5 computer, describes the physical appearance of the enclosure, and lists compatibility issues of interest to developers.
- Chapter 2, Architecture, (page 17) describes the internal organization of the computer. It includes a functional block diagram and descriptions of the main components on the logic board.
- Chapter 3, Input and Output Devices, (page 30) describes the built-in I/O devices and the external I/O ports.
- Chapter 4, Expansion, (page 57) describes the expansion slots on the logic board and provides specifications for the expansion modules.
- Appendix A, Supplemental Reference Documents, (page 64) provides sources of additional information about the technologies used in the Power Mac G5 computer.
- Appendix B, Conventions and Abbreviations, (page 69) lists standard units of measure and other abbreviations used in this developer note.

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Overview to the Power Mac G5

The 64-bit desktop Power Mac G5 uses dual PowerPC G5 microprocessors and is intended for use in content creation, desktop publishing, multimedia, scientific and technical applications, and other activities that require high performance.

New Hardware Features

Below is a list of the new hardware features of the Power Mac G5. A list of all hardware features is provided in Hardware Features Summary (page 9).

- **Microprocessors**: The Power Mac G5 computer is available in dual 2.0 GHz, 2.3 GHz, and 2.7 GHz configurations. For more information, see PowerPC G5 Microprocessor (page 20).
- **Graphics card**: The Power Mac G5 computer comes standard with one of the following graphics cards: the ATI Radeon 9600 with 128 MB RAM or the ATI Radeon 9650 with 256 MB RAM. The NVIDIA GeForce 6800 Ultra DDL with 256 MB RAM is a build-to-order option. For more information, see Graphics Cards (page 28).
- **Hard disks**: An internal 7200 rpm Serial ATA (SATA) hard disk occupies one of two drive bays and functions as the default boot disk. A second SATA drive is available as a build-to-order option. Hard disk capacities are 160 GB, 250 GB, and a 400 GB build-to-order option. For more information, see Serial ATA Interface (page 26).
- **Power supply**: The Power Mac G5 computer comes with a 450 W or 600 W power supply.
- **SuperDrive (DVD+R DL/DVD+/-RW/CD-RW)**: The Power Mac G5 computer has a 16x SuperDrive connected to the Ultra DMA ATA/100 bus. The SuperDrive supports DVR+R double-layer (DL) format. For more information, see SuperDrive (page 38).
- **Bluetooth 2.0 + EDR**: Available as a build-to-order option or as an Apple Authorized Service Provider kit. The fully-integrated Bluetooth 2.0 module with enhanced data rate (EDR) enables short-range wireless connections between desktop and laptop computers and a host of other peripheral devices. For more information, see Bluetooth Technology (page 42).

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Hardware Features Summary

Below is a list of all of the hardware features of the Power Mac G5. The major features are described more fully later in this note. To view the Technology and Performance Overview document, refer to http://www.apple.com/powermac/.

- **Microprocessors**: The Power Mac G5 computer is available in dual 2.0 GHz, 2.3 GHz, and 2.7 GHz configurations. For more information, see PowerPC G5 Microprocessor (page 20).
- **Processor system bus**: The processor interface system bus runs at half the speed of the system microprocessor. For more information, see Processor Bus (page 21).
- **Memory caches**: The PowerPC G5 microprocessors used in the Power Mac G5 computer have an internal 512 KB level 2 cache.
- **Memory bus**: The main memory bus is 128 bit 400 MHz. For more information, see Main Memory Bus (page 21).
- **DDR SDRAM**: Depending on configuration, the Power Mac G5 has four or eight DIMM slots for 184 pin DIMMs (dual inline memory modules) using unbuffered DDR (double data rate) SDRAM 64-bit, 400 MHz (PC3200) devices for a maximum of 4 GB or 8 GB. For more information, see Main Memory Bus (page 21).
- **Liquid cooling system**: One configuration has a liquid cooling system. For more information, see Liquid Cooling System (page 29).
- **AGP 8x Pro slot**: The computer has an AGP 8x Pro slot with an accelerated graphics card installed. For more information, see Accelerated Graphics Port Bus (page 21).
- **PCI expansion slots**: Some configurations support three 64-bit 33 MHz PCI slots. For more information, see PCI or PCI-X Expansion Slots (page 22).
- **PCI-X expansion slots**: Some configurations support three PCI-X expansion slots: one slot supports a maximum of 133 MHz and two slots support a maximum of 100 MHz. For more information, see PCI or PCI-X Expansion Slots (page 22).
- **Hyper Transport bus**: The Power Mac G5 supports the high-speed bus architecture between the memory controller and device I/O. For more information, see HyperTransport Technology (page 23).
- **Graphics card**: The Power Mac G5 computer comes standard with one of the following graphics cards: the ATI Radeon 9600 with 128 MB RAM or the ATI Radeon 9650 with 256 MB RAM. The NVIDIA GeForce 6800 Ultra DDL with 256 MB RAM is a build-to-order option.For more information, see Graphics Cards (page 28).
- **Hard disks**: An internal 7200 rpm Serial ATA (SATA) hard disk occupies one of two drive bays and functions as the default boot disk. A second SATA drive is available as a build-to-order option. Hard disk capacities are 160 GB, 250 GB, and a 400 GB build-to-order option. For more information, see Serial ATA Interface (page 26).
- **Power supply**: The Power Mac G5 computer comes with a 450 W or 600 W power supply.

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- **SuperDrive (DVD+R DL/DVD+/-RW/CD-RW)**: The Power Mac G5 computer has a 16x SuperDrive connected to the Ultra DMA ATA/100 bus. The SuperDrive supports DVR+R double-layer (DL) format. For more information, see SuperDrive (page 38).
- **Combo (DVD-ROM/CD-RW) drive**: Instead of a SuperDrive, the Power Mac G5 computer has an optional build-to-order combination DVD-ROM/CD-RW drive connected to the Ultra DMA ATA/100 bus. For more information, see Combo Drive (page 39).
- **High-speed USB 2.0**: The computer has three external USB 2.0 ports: two on the rear of the enclosure and one on the front. All ports support both high-speed and classic USB speeds. For more information, see USB Ports (page 30).
- **Ethernet**: The computer has a built-in Ethernet port for 10Base-T/UTP, 100Base-TX, or 1000Base-T Gigabit operation. The Ethernet port is auto-sensing and self-configuring to allow use of either a cross-over or straight-through cable. For more information, see Ethernet Port (page 36).
- **AirPort Extreme Card**: Available as a build-to-order option, the 54 Mbps AirPort Extreme Card provides a wireless LAN connection. For more information, see Wireless LAN Module (page 25).
- **Bluetooth 2.0+ EDR**: Available as a build-to-order option or as an Apple Authorized Service Provider kit. The fully-integrated Bluetooth 2.0 module with enhanced data rate (EDR) enables short-range wireless connections between desktop and laptop computers and a host of other peripheral devices. For more information, see Bluetooth Technology (page 42).
- **FireWire ports**: The computer has two FireWire 400 ports and one FireWire 800 port. For more information, see FireWire Controllers (page 26).
- **Modem**: The built-in Apple 56 Kbps modem is available as a build-to-order option or as an Apple Authorized Service Provider kit. The modem supports K56flex and V.90 and V.92 modem standards. For more information, see Internal Modem (page 40).
- **Keyboard**: The computer comes with a full-size USB Apple Keyboard. The keyboard is also a bus-powered USB hub with two USB ports. For more information, see Keyboard (page 43).
- **Mouse**: The computer comes with a USB Apple Mouse, with optical tracking. For more information, see Mouse (page 46).
- **Boot ROM**: The Power Mac G5 computer comes with 1 MB of boot ROM.
- **Optical digital audio**: The Power Mac G5 implements optical digital audio I/O via S/PDIF (Sony/Phillips Digital Interface) TOSLink input and output connectors on the rear panel. For more information, see Sound System Overview (page 27).
- **Analog audio line-in**: Rear panel analog audio line-in port for self-powered microphones or other audio equipment. For more information, see Audio Line-in (page 49).
- **Analog audio line-out**: Rear panel analog audio line-out port for externally-powered speakers or other audio devices with line-level outputs. For more information, see Audio Line-out (page 49).

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- **Headphone and internal speaker**: The front panel includes a headphone mini-jack and the system includes an internal front mono speaker. For more information, see Headphone Jack (page 50).
- **DVI to video adapter**: The Power Mac G5 supports S-video and composite video from an optional adapter connected to the DVI port. For more information, see DVI to Video Adapter (page 55).
- **Voltage switching**: Auto-ranging voltage switching accepts 100 - 240V.
- **Fan speed control**: The speeds of the fans are controlled by thermal/wattage factors and are automatically set as low as possible to minimize noise.
- **Dimensions and weight**: Power Mac G5 dimensions are 20.12" (51.1 cm) high by 8.11" (20.6 cm) wide by 18.70" (47.5 cm) deep and weighs approximately 44.4 pounds (20.2 kg).
- **Energy saving**: Sleep scheduling can be controlled via the Energy Saver pane in System Preferences.

> **Note:** While in sleep mode, the computer emits no noise and the power light pulses slowly.

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Features of the Enclosure

The Power Mac G5 computer's enclosure is a tower design. Figure 1-1 (page 12) illustrates the front of the enclosure and Figure 1-2 (page 13) illustrates the rear of the enclosure.

Figure 1-1 Power Mac G5 front view

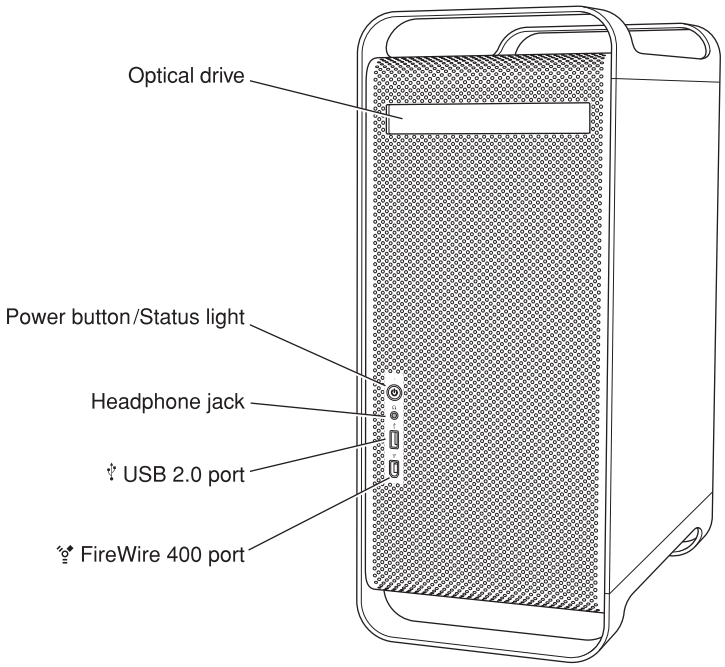

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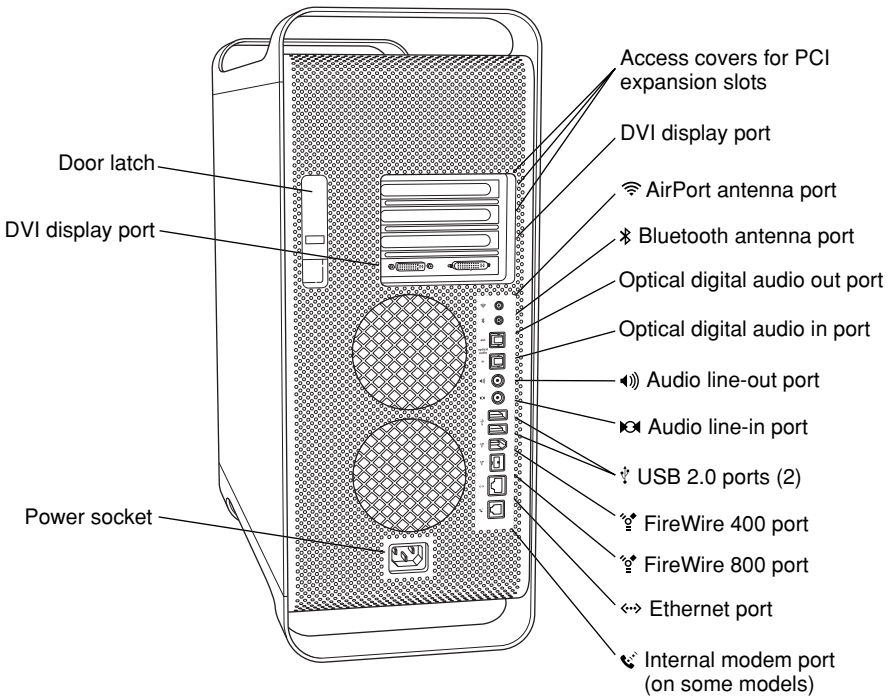
Figure 1-2 Power Mac G5 rear view



The enclosure has space for two hard disk drives and one optical device. See Hard Disk Drives (page 38).

To access the main logic board to install PCI or PCI-X cards or additional memory, refer to Expansion (page 57). For full details regarding opening and accessing the computer, refer to the *Power Mac G5 User's Guide* that was shipped with your computer.

Warning: Opening the enclosure side panel impacts the thermal performance of the computer. Do not run the enclosure with the side panel open. If the air deflector inside the enclosure is removed, the fans will spin very slowly and the system will take action to prevent over-heating.

System Software

The Power Mac G5 ships with Mac OS X 10.4 installed as the default operating system. The classic environment can be used to run Mac OS 9 applications. Load the Classic application from the system software optical disk that shipped with your computer.

To retrieve information from the I/O Registry, use the APIs in the header file IOKit/IOKitLib.h.

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Computer Identification

Rather than reading the box flag or the model string and then making assumptions about the computer's features, applications that need to find out the features of the computer should use I/O Registry calls to test for the features they require.

Asset management software that reports the kind of computer it is run on can obtain the value of the property at `Devices:device-tree:compatible` in the IODeviceTree plane of the I/O Registry. The model string is the first program-usable string in the array of C strings in the `compatible` field. For the Power Mac G5 2.0 GHz and 2.3 GHz configurations, the value of the model property is `PowerMac7,2` ; the 2.7 GHz configuration model property value is `PowerMac7,3` .

> **Note:** To differentiate these models of the Power Mac G5 from previous versions, look at the EMC number on the label on the back of the computer. This developer note addresses EMC number 2061.

Power Management

The basics of Power Mac G5's power management techniques are described in the following paragraphs.

Processor and Bus Slewing

To lower power consumption, heat generation, and fan noise, the Power Mac G5 computer incorporates an automatic power management technique called bus slewing. Bus slewing is designed to run at high processor/bus speeds and high voltage when the demand on the processor is high, and to run at low processor/bus speeds and low voltage when the demand on the processor is low.

> **Note:** The memory bus runs at 400 MHz and does not slew.

Switching between different processor/bus speeds and voltages is achieved by a gradual transition that is designed to minimally impact system or application performance and typically operates seamlessly to the user. In slewing, the bus runs at half the speed of the processor.

The ranges of the slewed processor speeds are listed below:

Configuration	Processor range
2.0 GHz	1.8 GHz to 2.0 GHz
2.3 GHz	1.8 GHz to 2.3 GHz
2.7 GHz	2.0 GHz to 2.7 GHz

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In addition, the Power Mac G5 computer allows the user to control bus slewing mode. The options for specifying either high, reduced, or automatic processor and bus speeds are located at System Preferences>Energy Saver>Options; then select Automatic, Highest, or Reduced.

> **Note:** For best performance when using professional applications with high demand on the system (such as Final Cut Pro or Logic), you may want to set the processor/bus speed option to highest.

If the Power Mac G5 computer detects a processor temperature that is high, due to high ambient temperatures or other factors, it will automatically enter bus slewing mode regardless of the selected setting.

Processor States

The following processor states are defined:

- Run: The system is running at maximum processing capacity with all processors running at full speed.
- Idle: The system is idling; this is the default state. All clocks are running and the system can return to running code within a few nanoseconds. If the system has no work to do, it will be in idle mode.

System Modes

The Macintosh system has the following power-saving modes. If the system does not support full sleep, it will use the less efficient doze mode.

- Run: The system is fully functional in normal operating mode with all components powered and operating.
- Doze: The power to the disk drive motors and the display is turned off, but the power supply and fans are still on. PCI cards that don't support full system sleep (some SCSI cards, some graphics cards) will cause the machine to doze rather than fully sleep.
- Full sleep: The main power supply is shut down. A trickle supply provides auxiliary power to the PCI slots and keeps the DRAM state preserved for a quick recovery. All processors are powered off with their state preserved in DRAM. All non-essential clocks in the system are suspended. This mode allows the computer to meet Energy Star sleep requirements while providing the ability to start up without rebooting. This system may be awakened by administrative network packets, keyboard or mouse activity, USB device insertion or removal, or PMU scheduled wakeup.
- Off: The Power Mac G5 computer meets FEMP (Federal Energy Management Program) requirements and supports FireWire ports functioning as repeaters when operating on AC power.

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Velocity Engine Acceleration

The Velocity Engine is the vector processing unit in the PowerPC G5 microprocessor. System software has been modified to take advantage of the accelerated processing that the Velocity Engine makes possible and to support low-level operations using the Velocity Engine.

For complete information on the Velocity Engine, refer to the following Apple website:

http://developer.apple.com/hardwaredrivers/ve/index.html

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Architecture

This chapter describes the architecture of the Power Mac G5. It includes information about the major components on the logic boards: the microprocessor, the other main ICs, and the buses that connect them to each other and to the I/O interfaces.

Block Diagram and Buses

The architecture of the Power Mac G5 is based on the PowerPC G5 microprocessor, and two custom ICs: the U3H memory controller and bus bridge and the K2 I/O controller.

Figure 2-1 (page 18) is a simplified block diagram of the dual processor 2.0 GHz Power Mac G5. The diagram shows the U3H and K2 ICs and the buses that connect them together.

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Figure 2-2 (page 19) is a simplified block diagram of the dual processor 2.3 and 2.7 GHz Power Mac G5. The diagram shows the U3H and K2 ICs and the buses that connect them together.

Figure 2-1 block diagram for dual 2.0 GHz configuration

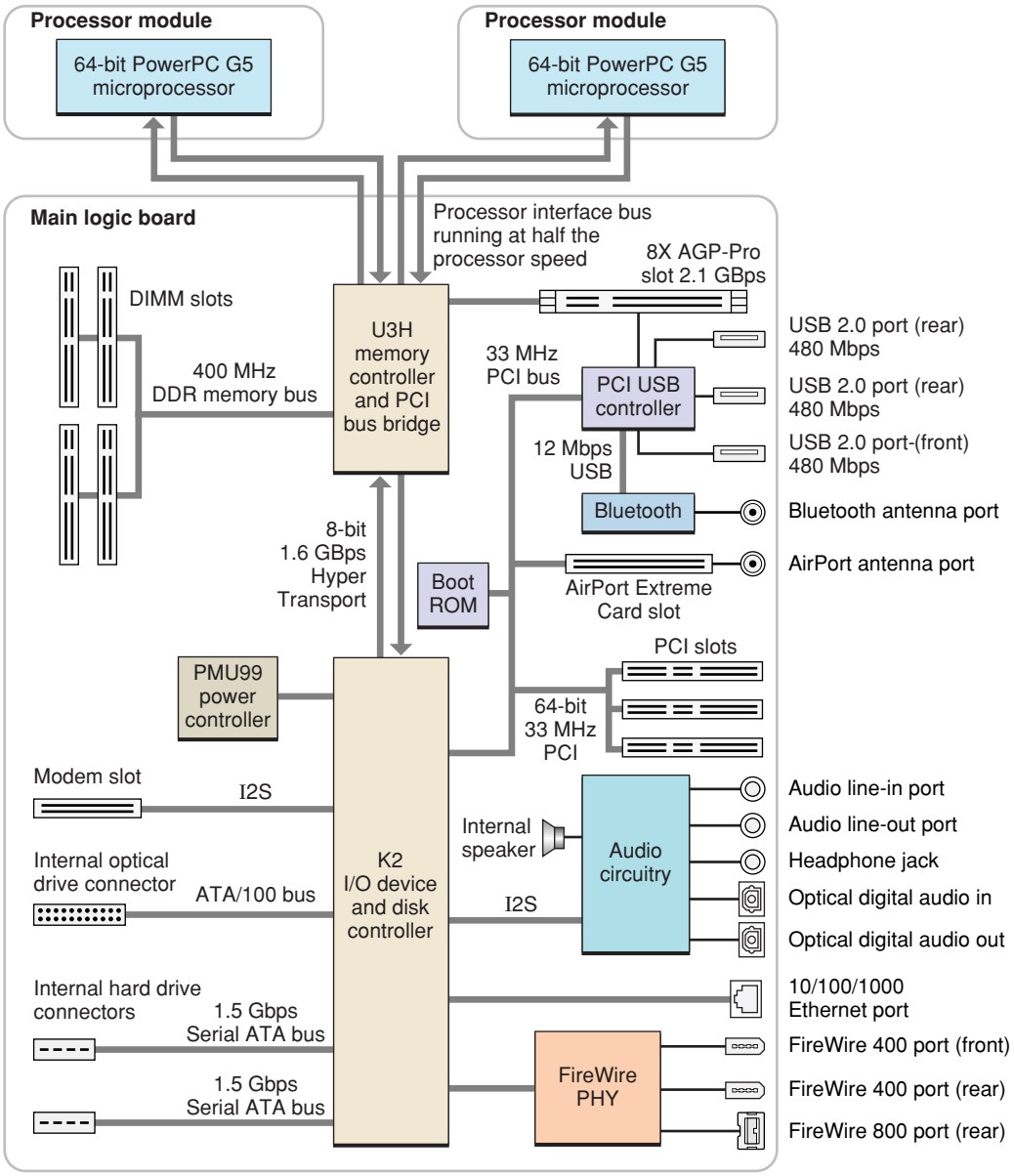

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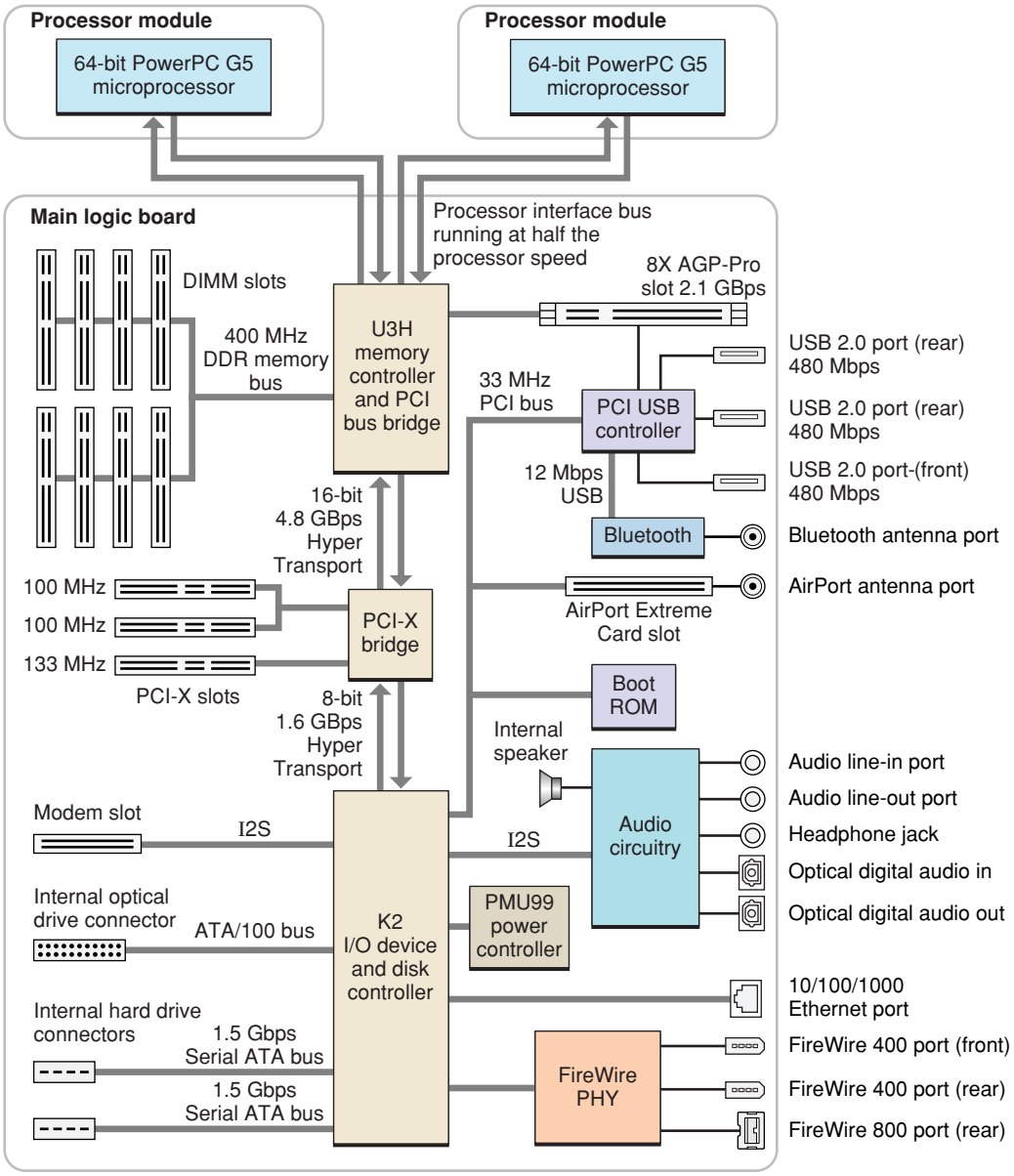
Figure 2-2 block diagram for dual 2.3 and 2.7 GHz configurations



The Power Mac G5 computer has the following data buses, not counting the processor's dedicated interface to the backside cache.

- Dual processor bus: 1 GHz/1.15 GHz/1.35 GHz (running at half the speed of the processor), 64-bit (32-bit in and 32-bit out) data throughput per processor connecting the processor module to the U3H IC
- Dual processor systems have two independent 64-bit processor buses
- Memory bus: 400 MHz, 128-bit bus connecting the main DDR SDRAM memory to the U3H IC
- 8x AGP Pro bus: 266/533 MHz, 32-bit bus connecting the AGP graphics card to the U3H IC
- PCI bus: some configurations support three 64-bit 33 MHz PCI slots

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- PCI-X bridge bus: some configurations support three 64-bit PCI-X slots: two 100 MHz and one 133 MHz
- Internal PCI bus: 33 MHz, 64-bit bus supports the K2 I/O controller, the boot ROM, the AirPort Extreme Card slot, the USB controller, and in some configurations the Bluetooth module
- Serial ATA (SATA) buses: support 1.5 Gbps internal hard drive connectors
- Ultra DMA ATA/100 bus: supports internal optical drive
- HyperTransport: high-speed, bidirectional, point-to-point link for integrated circuits supports bidirectional data rates up to 4.8 GBps, on applicable configurations

The remainder of this chapter describes the architecture of the processor module, the U3H memory controller and bridge IC, the K2 I/O controller IC, and the USB controllers.

Processor Module

The dual processor Power Mac G5 contains two identical PowerPC G5 processor modules. Each processor module is connected to the main logic board by a 300-pin connector. To achieve the required level of performance, the signal lines that connect the processor module and the main logic board are carefully matched in length, loading, and impedance.

PowerPC G5 Microprocessor

The PowerPC G5 used in the Power Mac G5 computer has the following features:

- 64-bit PowerPC implementation with 42-bit physical memory addressing
- core runs at twice the bus speed
- superscalar execution core supporting more than 200 in-flight instructions
- two independent double-precision floating point units
- Velocity Engine: 128-bit-wide vector execution unit
- 64K L1 instruction cache, 32K L1 data cache per processor
- fully symmetric multiprocessing capability
- built-in 512 KB backside L2 cache per processor
- two independent, unidirectional 1.0 GHz to 1.35 GHz frontside buses each supporting up to 10.8 GBps data throughput per processor

For more information, see the reference at PowerPC G5 Microprocessor (page 64).

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Bridge and Memory Controller

The U3H custom IC is at the heart of the Power Mac G5 computer. It provides the bridging functionality among the processors, the memory system, HyperTransport bus to the PCI-based I/O system, and the AGP slot.

Processor Bus

The processor bus is a 1 GHz, 1.15 GHz or 1.35 GHz bus connecting the processor module to the U3H IC. The bus has 64-bit (32-bit in and 32-bit out) wide data and 36-bit wide addresses.

The Power Mac G5 system controller is built with 130-nanometer, SOI technology. This super-efficient point-to-point architecture provides each subsystem with dedicated bandwidth to main memory. The Power Mac G5 uses separate processor boards with each PowerPC G5 processor; two processor boards are used for the Power Mac G5's dual processor design. The U3H I/O implements two independent processor interfaces. The processor clock is derived from a PLL which multiplies the reference clock by preset intervals of 8 times.

Out-of-order completion allows the memory controller to optimize the data bus efficiency by transferring whichever data is ready, rather than having to pass data across the bus in the order the transactions were posted on the bus. This means that a fast DDR SDRAM read can pass a slow PCI read, potentially enabling the processor to do more before it has to wait on the PCI data.

Intervention is a cache-coherency optimization that improves performance for dual-processor systems. If one processor modifies some data, that data first gets stored only in that processor's cache. If the other processor then wants that data, it needs to get the new modified values.

Main Memory Bus

The Power Mac G5 computer main memory bus connects the main memory to the U3H IC via the 128-bit data bus. The memory modules are 400 MHz (PC3200) DDR SDRAM DIMMs with a per system maximum of 4 GB or 8 GB, depending on the configuration.

Standard supported DIMM sizes are 128, 256, 512 MB, and 1 GB. The DIMMs must be unbuffered and installed in pairs of the same size.

For more information about memory DIMMs and installation, see RAM Expansion (page 57).

Accelerated Graphics Port Bus

The accelerated graphics port (AGP 8x Pro) bus is a 266/533 MHz, 32-bit bus connecting the AGP card to the U3H IC. DDR data is transmitted at both edges of the clock for peak transfers of 2.1 GBps.

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The AGP bus is an enhanced PCI bus with extra functionality to burst texture data and other graphics across the port up to 8 times faster than a 66 MHz PCI port. The Power Mac G5 computer's AGP implementation is compatible with version 3 of the AGP specification and with the Pro version of AGP. AGP 3.0 enables deeply pipelined memory read and write operations and demultiplexing of address and data on the bus.

To further improve the performance of the AGP bus, the U3H IC supports a graphics address remapping table (GART). Because the virtual memory system organizes main memory as randomly distributed 4 KB pages, DMA transactions for more than 4 KB of data must perform scatter-gather operations. To avoid this necessity for AGP transactions, the GART is used by the AGP bridge in the U3H to translate a linear address space for AGP transactions into physical addresses in main memory.

The U3H IC also supports a DMA Address Relocation Table (DART) that provides the same functions for AGP as does the GART, except that the functions are for devices attached to HyperTransport. Most device drivers do not require special knowledge of the DART because IOKit will configure it automatically if the driver uses IOMemoryDescriptors.

For more information on the graphics cards installed in the AGP slot, refer to Graphics Cards (page 28).

Note: The AGP bus is 1.5 V only and is not backward compatible. Older AGP cards will not work in the Power Mac G5 computer.

Internal PCI Bus

An internal 33 MHz, 64-bit PCI bus connects the K2 I/O controller to the boot ROM, the AirPort Extreme Card slot, and the USB controller. The U3H IC used in the Power Mac G5 computer supports the PCI write combining feature. This feature allows sequential write transactions involving the Memory Write or Memory Write and Invalidate commands to be combined into a single PCI transaction. For memory write transactions to be combined, they must be sequential, ascending, and non-overlapping PCI addresses. Placing an `eieio` or `sync` command between the write commands prevents any write combining.

For more information on the PCI bus, refer to PCI or PCI-X Expansion Slots (page 62).

PCI or PCI-X Expansion Slots

In some configurations, the Power Mac G5 computer provides three 64-bit 33 MHz PCI slots that interface to the K2 I/O and share the bus with the USB controller.

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In some configurations, the Power Mac G5 computer provides three PCI-X slots that interface to the HyperTransport bus via the PCI-X bridge. One slot runs at a maximum of 133 MHz and two slots run at a maximum of 100 MHz. The 133 MHz slot can support a maximum burst bandwidth of 1064 MBps, based on 64 bits times 133 MHz. The two 100 MHz slots can support a combined bandwidth of 800 MBps. It is recommended that the highest bandwidth card be inserted in the 133 MHz PCI-X slot labeled slot 4.

Each slot has room for a full size 12.335-inch or short 6.926-inch card. The slots are numbered from 2 to 4 on back panel, on the PCB, and in the Apple System Profiler. Slot one is the AGP.

Note: The Power Mac G5's build-to-order NVIDIA GeForce 6800 Ultra DDL graphics card occupies both the AGP slot and the adjacent PCI slot. As a result, you can install PCI expansion cards in the slots labeled 3 and 4 but not in slot 2. To learn more about installing PCI cards, refer to the *Power Mac G5 User's Guide* that came with your computer. For more information on graphics cards and PCI power availability, refer to Graphics Cards (page 28).

The connectors to the PCI or PCI-X slots are 3.3 V keyed and support 32-bit and 64-bit buses. The connectors include a PME signal which allows a PCI card to wake the computer from sleep.

Note: 5 V keyed or signalling cards do not work in the Power Mac G5 computer.

The slots (12.335 inch) have a capture feature which is at the end of the slot. If a card exceeds the short length it is recommended that the long length be used rather than an intermediate length, to assure the card stays secure if and when the system is in shipment.

For more information, refer to PCI or PCI-X Expansion Slots (page 62).

HyperTransport Technology

The DDR HyperTransport is an advanced chip-to-chip communications technology that provides a high-speed, high-performance, point-to-point link for integrated circuits. HyperTransport provides a universal connection that reduces the number of buses within a system.

In the configuration without a PCI-X bridge, the HyperTransport bus between the U3H the K2 IC is 8 bits wide in both directions and supports a total of 1.6 GBps bidirectional throughput.

In the configurations with a PCI-X bridge, the HyperTransport bus between the U3H IC and the PCI-X bridge is 16 bits wide in both directions and supports a total of 4.8 GBps bidirectional throughput. Between the PCI-X bridge and the K2 IC, the bus width is 8 bits, supporting total of 1.6 GBps bidirectional throughput.

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For more information on the HyperTransport technology, go to the World Wide Web at

http://www.hypertransport.org

PCI USB Controller

The Power Mac G5 CPU uses a PCI USB controller ASIC with one Enhanced Host Controller Interface (EHCI) function and two Open Host Controller Interface (OHCI) functions. The controller has a total of five ports available to support three external USB ports and the internal AGP slot, which goes through the AGP to support the USB hub on the Apple display. The PCI USB controller also supports the Bluetooth and AirPort Express interfaces. If connected to classic-speed USB devices, the two rear panel ports are connected to separate OHCI controllers.

The five USB ports comply with the Universal Serial Bus Specification 2.0. The USB register set complies with the EHCI and OHCI specifications. For more information, see USB Ports (page 30).

K2 I/O Controller

The K2 custom IC provides all the I/O functions. These functions are described in the following sections.

DMA Support

The K2 IC provides DB-DMA (descriptor-based direct memory access) support for the following I/O channels:

- Ultra ATA/100
- Ethernet interface
- FireWire interface
- I2S channel to the sound subsystem
- Serial ATA

The DB-DMA system provides a scatter-gather process based on memory-resident data structures that describe the data transfers. The DMA engine is enhanced to allow bursting of data files for improved performance.

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Wireless LAN Module

The AirPort Extreme Card wireless LAN module (via the PCI USB controller) contains a media access controller (MAC), a digital signal processor (DSP), and a radio-frequency (RF) section. The module is wired to an antenna port on the rear of the computer.

The AirPort Extreme Card is compliant with the IEEE 802.11g standard. The card transmits and receives data at up to 54 Mbps and is compatible with Apple AirPort systems as well as other 802.11b and 802.11g Wi-Fi certified products. For information about its operation, see AirPort Extreme Card (page 40).

The internal Bluetooth module connectivity comes off the PCI USB controller. See Bluetooth Technology (page 42) for more information.

Modem Slot Support

The K2 IC supports the modem and provides DB-DMA (descriptor-based direct memory access) support for the modem slot interface. The modem is connected via an I2S interface.

The internal hardware modem is a separate module that contains a modem controller IC, a data pump, and the interface to the telephone line (DAA). For more information about the modem, see Internal Modem (page 40).

Boot ROM

The boot ROM consists of 1 MB of on-board flash EEPROM. The boot ROM includes the hardware-specific code and tables needed to start up the computer using Open Firmware, to load an operating system, and to provide common hardware access services.

Ethernet Controller

The K2 IC includes an Ethernet media access controller (MAC) and PHY. As a separate I/O channel on the K2 IC, it can operate at its full capacity without degrading the performance of other peripheral devices.

The MAC implements the link layer. It is connected to a PHY that is internal to K2 and provides 10Base-T/UTP, 100Base-TX, or 1000Base-T operation over a standard twisted-pair interface. The Ethernet port is auto-sensing and self-configuring to allow use of either a cross-over or straight-through cable. The operating speed of the link is automatically negotiated by the PHY and the bridge, router, hub, switch, or other Mac or PC to which the Ethernet port is connected.

For information about the Ethernet port, see Ethernet Port (page 36).

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FireWire Controllers

The K2 IC includes a FireWire controller that supports both IEEE 1394b (FireWire 800) with a maximum data rate of 800 Mbps (100 MBps) and IEEE 1394a (FireWire 400) with a maximum data rate of 400 Mbps (50 MBps). The IC is backwards-compatible with 1394a (FireWire 400). The K2 IC provides DMA (direct memory access) support for the FireWire interface.

The controller in the K2 IC implements the FireWire link layer. A physical layer IC, called a PHY, implements the electrical signaling protocol of the FireWire interface and provides the electrical signals to the ports.

For more information, see FireWire Ports (page 32).

Interrupt Support

The interrupt controller is an MPIC cell in the K2 IC. In addition to accepting internal interrupt sources from the I/O, the MPIC controller accepts internal interrupts from U3H and dedicated interrupt pins.

USB Interface

The K2 IC has two independent USB OHCI controllers. The external USB interface is via the PCI USB controller; see PCI USB Controller (page 24).

Serial ATA Interface

Based on the Serial ATA 1.0 specification, Serial ATA (SATA) is a disk-interface technology that delivers up to 1.5 Gbps of performance to each independent drive bus on the Power Mac G5 computer. It provides a scalable, point-to-point connection that allows multiple ports to be aggregated into a single controller. Serial ATA uses a thin, point-to-point cable connection that enables easy routing within a system, avoiding master/slave, daisy-chaining, and termination issues and enabling better airflow within a system.

The K2 IC implements two Serial ATA revision one ports, each of which accommodates one independent internal hard drive.

For information about the drive bays, see Hard Disk Drives (page 38).

Ultra DMA ATA/100 Interface

The K2 IC provides an Ultra DMA ATA/100 interface to support the optical drive. For information about specific drives, see Disk Drives (page 38).

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Sound System Overview

The sound circuitry is connected to the K2 IC by a standard I2S (inter-IC sound) bus. The K2 IC provides DB-DMA (descriptor-based direct memory access) support for the I2S port.

The Power Mac G5 circuitry consists of two main components: an analog audio CODEC IC and a digital audio CODEC IC. The analog audio CODEC IC includes an A/D converter, a D/A converter, and digital audio processing functions. The digital audio processing functions include output equalization, dynamic range compression, and volume control. The equalization and dynamic range control functions are set to fixed values to equalize the internal speaker. Those functions are bypassed for signals sent to the audio output jacks.

Stereo signals from the audio input jack are routed to an analog line input buffer that drives the internal A/D converter in the analog CODEC. The output of the A/D converter is routed to the K2 IC over the I2S bus.

Digital audio data from the K2 IC is routed to the D/A converter on the analog audio CODEC over the I2S bus. The analog audio output from the D/A converter is routed to separate amplifiers that drive the line output, headphone output, and internal speaker.

The digital audio CODEC IC includes an S/PDIF (Sony/Phillips Digital Interface) digital audio receiver, a sample rate converter (SRC), a phase-locked loop (PLL), and an S/PDIF digital audio transmitter.

The S/PDIF input can operate in synchronous and asynchronous modes. In synchronous mode, the PLL in the digital audio CODEC locks on to the incoming S/PDIF data rate and drives the audio system clocks in the Power Mac G5, allowing bit-accurate data processing of the S/PDIF input data. In asynchronous mode, the incoming S/PDIF data passes through the SRC, where it is converted to the output sample rate of the Power Mac G5, allowing the Power Mac G5 to play audio at a fixed output sample rate while accepting S/PDIF input data over a wide frequency range. The audio data from the S/PDIF receiver is routed to the K2 IC over the I2S bus.

Digital audio data from the K2 chip is routed to the S/PDIF output transmitter in the digital audio CODEC over the I2S bus. The Power Mac G5 sends and receives S/PDIF audio data over TOSLink optical connectors.

Analog audio I/O is not independent of digital audio I/O on the Power Mac G5. Audio input can come from either the line input or the S/PDIF input, but not both at the same time. Audio output can be played simultaneously on the line out, headphones output, and S/PDIF output. However, these audio streams are not independent.

The speaker output is mutually exclusive from the line out, headphones out and S/PDIF outputs. If the speaker output is selected, the line output, the headphones output and the S/PDIF output are disabled. If any of the line output, the headphones output, or the S/PDIF output are selected, the speaker output is disabled.

When the speaker output is active, the digital audio processing functions in the analog CODEC are used to implement output equalization for the internal speaker, resulting in improved sound quality from the internal speaker.

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For more detail on the audio, see Audio (page 46).

Power Controller

The power management controller in the Power Mac G5 computer is a microcontroller called the PMU99. It supports new modes of power management that provide significantly lower power consumption than earlier systems. The Power Mac G5 also utilizes a service processor unit and a fan controller unit (refer to Fan Controller (page 29)).

For more information on power management strategy, see Power Management (page 14).

Graphics Cards

The Power Mac G5 comes with a high-performance AGP graphics card with DDR SDRAM memory. Table 2-1 lists the supported graphics cards, video memory, and power.

Table 2-1 Graphics Cards SDRAM and Power

Graphics IC	Video SDRAM	Power usage	PCI power available
ATI Radeon 9600	128 MB	15W	75 W
ATI Radeon 9650	256 MB	15 W	75 W
NVIDIA GeForce 6800 Ultra DDL (build-to-order)	256 MB	105 W	30 W

The build-to-order GeForce 6800 Ultra DDL occupies both the AGP slot and the adjacent PCI slot. For information on PCI expansion slots, refer to PCI or PCI-X Expansion Slots (page 22).

All graphics cards support dual displays in either extended desktop or video mirroring mode, and the dual-link cards support a 30" Apple Cinema HD display at digital resolutions up to 2560x1600 pixels and analog resolutions up to 1600x1200 pixels. For information about the graphics cards' ports and modes, see Video Monitor Ports (page 51).

The display memory on the AGP card is separate from the main memory. The display memory consists of 128 MB or 256 MB of DDR devices configured to make a 128-bit data bus. The display memory cannot be expanded by the user.

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Fan Controller

The Power Mac G5 system employs advanced thermal and wattage management to keep acoustic noise to a minimum. The enclosure is divided into discrete zones, each with independently controlled fans bringing in cool air from the front of the enclosure, directing it over system components and exhausting it out the rear. Temperature and power consumption are monitored by the operating system which communicates with the Fan Control Unit, which in turn controls and monitors fan operation. Note that if Mac OS X is not booted, thermal management must be provided by the alternate development operating system.

Fan Control Unit (FCU) controls the fans and pumps in the Power Mac G5 and regulates the speeds to run each fan. The FCU derives fan speed from sensors in each thermal zone. Some of these sensors are thermal while others monitor power/wattage used in a particular area. It is important to note that there are fixed limits to fan speed in those areas where power sensors are used. At the upper limits, a fan could be fixed at a particular speed, based on power consumption, even though that zone continues to generate more heat.

If the FCU does not receive an update from the operating system within two minutes, it begins to ramp up the speed of the fans to full speed.

Liquid Cooling System

The 2.7 GHz configuration of the Power Mac G5 uses a liquid cooling system controlled by Mac OS X to manage the temperature of the processors in the computer. The liquid cooling system works in conjunction with the air cooling system and is designed to to optimally cool internal components as quietly as possible. The liquid cooling system is sealed and is not designed to be opened.

Warning: Do not attempt to open or service the liquid cooling system. Opening the liquid cooling system may damage your equipment, and such damage may not be covered by the limited warranty on your computer.

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Input and Output Devices

This chapter describes the Power Mac G5 computer's built-in I/O devices and the ports for connecting external I/O devices. Each of the following sections describes an I/O port or device.

USB Ports

The Power Mac G5 computer has two external Universal Serial Bus (USB) 2.0 ports on the back and one on the front of the enclosure and an internal connection to the AGP slot for the Apple display. The external USB ports are off of the USB controller connected to the PCI bus, bridged by K2. In addition, there are two USB 1.1 ports on the keyboard. The USB ports are used for connecting the keyboard and mouse as well as additional I/O devices such as printers, scanners, and storage devices.

All USB ports are fully compliant with the USB 2.0 specification, including support for high-speed (480 Mbps) devices using an Enhanced Host Controller Interface (EHCI). Ports are automatically routed to a companion OHCI controller when a classic-speed (full-speed or low-speed) USB device is attached to a root hub port.

Each USB rear port is connected to a separate USB root hub in classic speeds, allowing the USB ports to support 12 Mbps devices at the same time with no degradation of their performance. The USB root hubs are also connected to the internal USB modem.

The three external USB ports comply with the Universal Serial Bus Specification 2.0. The two ports on the keyboard comply with the Universal Serial Bus Specification 1.1 Final Draft Revision. For low-speed and full-speed devices, the USB register set complies with the Open Host Controller Interface (OHCI) specification. For high-speed devices, the USB register set complies with the Enhanced Host Controller Interface (EHCI) specification.

For more information about USB on Macintosh computers, please refer to Apple Computer's *Accessing Hardware from Applications* and the other sources listed in USB Interface (page 67).

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USB Connectors

The USB ports use USB Type A connectors, which have four pins each. Two of the pins are used for power and two for data. Figure 3-1 (page 31) shows the connector and Table 3-1 (page 31) shows the signals and pin assignments.

Figure 3-1 USB connector

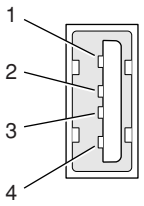

Table 3-1 Signals on the USB connector

Pin	Signal name	Description
1	VCC	+5 VDC
2	D–	Data –
3	D+	Data +
4	GND	Ground

The Power Mac G5 computer provides 5 V power for the USB ports and up to 500 mA on each port. The power is provided in both run and sleep mode. The ports share the same power supply; a short circuit on one disables all ports until the short has been removed.

The USB ports support all USB 2.0 speeds: high-speed (480 Mbps) and classic USB speeds of full-speed (12 Mbps) and low-speed (1.5 Mbps). High-speed operation requires the use of shielded cables.

The Macintosh system software supports all four data transfer types defined in the USB specification, as well as split transactions for classic-speed devices attached to high-speed hubs.

Waking Up From Sleep

As defined in the USB-suspend mode of the USB specification, USB devices can provide a remote wakeup function for the computer (resume signalling). The USB root hub in the computer is set to support remote wakeup whenever a device is attached to the bus. The device wakes the computer by sending a RESUME event to the USB root hub. The mouse and keyboard that come with the computer use this method to wake the computer on a key press or mouse click.

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FireWire Ports

The Power Mac G5 computer has one FireWire 800 port based on IEEE 1394b and two FireWire 400 IEEE 1394a ports. Each FireWire port

- supports booting the system from a mass storage device
- supports target disk mode
- provides bus repeating capability as long as the computer is connected to AC power
- provides power for FireWire devices both in run and sleep mode (useful for charging the iPod)

The three FireWire ports share a single power supply that can provide up to 15 watts total. The three ports are all on the same FireWire bus and can connect to up 62 other FireWire devices.

The FireWire hardware and software provided with the Power Mac G5 computer are capable of all asynchronous and isochronous transfers defined by IEEE standards 1394a and 1394b.

Note: FireWire cables are not included with this product and must be purchased independently, if required.

For more information about FireWire on Macintosh computers, please refer to the Apple FireWire website and the other sources listed in FireWire Interface (page 67).

FireWire 800 Connector

The FireWire 800 port on the Power Mac G5 computer is based on IEEE 1394b and enables a 800 Mbps transfer rate. FireWire 800 uses a 9-pin connector and is backwards compatible with original 1394a (FireWire 400) devices with 6-pin or 4-pin connectors. With the appropriate cable, the 9-pin port works seamlessly with legacy FireWire devices. Cables are available to go from both 6-pin and 4-pin connectors to a 9-pin, and 9-pin to 9-pin.

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The 9-pin FireWire 800 connector is shown in Figure 3-2 (page 33). Its connector signals and pin assignments are shown in Table 3-2 (page 33).

Figure 3-2 9-pin FireWire 800 connector

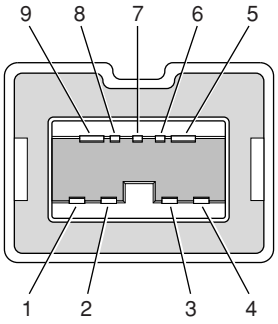

Table 3-2 Signals on the 9-pin FireWire 800 connector

Pin	Signal name	Description
1	TPB–	Twisted-pair B Minus
2	TPB+	Twisted-pair B Plus
3	TPA–	Twisted-pair A Minus
4	TPA+	Twisted-pair A Plus
5	TPA (R)	Twisted-pair A Ground Reference
6	VG	Power Ground
7	SC	Status Contact (no connection; reserved)
8	VP	Power Voltage (approximately 25 V DC)
9	TPB (R)	Twisted-pair B Ground Reference

VP (pin 8) provides up to 15 W power, shared with the other FireWire connectors. The voltage on the power pin is approximately 25 V.

The 9-pin FireWire port is capable of operating at 100, 200, 400, and 800 Mbps, depending on the device it is connected to. Using a cable with a 9-pin connector at one end and a 4-pin or 6-pin connector at the other, the 9-pin port is capable of directly connecting to all existing FireWire devices. Using a cable with 9-pin connectors at both ends, the 9-pin port is capable of operating at 800 Mbps.

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The IEEE 1394b standard defines long-haul media using Cat 5 UTP and several kinds of optical fiber. The Power Mac G5 computer is interoperable with such cables but cannot be directly connected to them. To use long-haul cables, connect the computer to a 1394b hub that has the desired kind of long-haul connectors. If the hub has a bilingual port, that port can be connected to any of the computer's FireWire ports. If the hub has a beta-only port, it can be connected only to the computer's 9-pin port.

FireWire 400 Connector

The FireWire 400 ports 1 and 2 use the six-pin connectors shown in Figure 3-3 (page 34). The connector signals and pin assignments are shown in Table 3-3 (page 34).

Figure 3-3 6-pin FireWire 400 connector

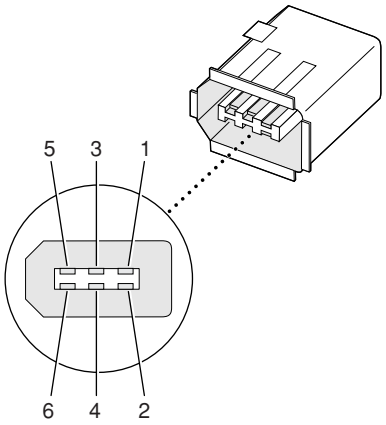

Table 3-3 Signals on the 6-pin FireWire 400 connector

Pin	Signal name	Description
1	Power	Power (approximately 25 V DC)
2	Ground	Ground return for power and inner cable shield
3	TPB–	Twisted-pair B Minus
4	TPB+	Twisted-pair B Plus
5	TPA–	Twisted-pair A Minus
6	TPA+	Twisted-pair A Plus
Shell	—	Outer cable shield

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The power pin provides up to 15 W total power, shared with the other FireWire connectors. The voltage on the power pin is approximately 25 V.

Pin 2 of the 6-pin FireWire connector is ground return for both power and the inner cable shield. In a FireWire cable with a 4-pin connector on the other end, the wire from pin 2 is connected to the shell of the 4-pin connector.

The signal pairs are crossed in the cable itself so that pins 5 and 6 at one end of the cable connect with pins 3 and 4 at the other end. When transmitting, pins 3 and 4 carry data and pins 5 and 6 carry clock; when receiving, the reverse is true.

FireWire Device Programming

Mac OS X includes general support for the FireWire bus and specific support for various kinds of FireWire devices and protocols. Developers can use the built-in support or provide additional applications and drivers for use with their products.

The general FireWire services will configure the FireWire bus, scan the bus for new devices, and allow multiple drivers and devices to share a single FireWire interface cooperatively. The general services also publish information about the bus and the devices in the IO Registry, so that IO Kit can match protocols and drivers to each connected FireWire device.

The specific device and protocol support in Mac OS X as provided with the Power Mac G5 includes the following:

- General services for Serial Bus Protocol 2 (SBP-2) and support for most mass storage devices using SBP-2, such as hard disk drives, optical drives, flash card readers, Target Disk Mode (see Target Disk Mode (page 36)), and the iPod. Mac OS X can boot from most of these devices.
- General services for the Audio Video Control (AV/C) protocol and support for most digital video (DV) cameras and decks using this protocol, including video capture through standard QuickTime APIs.
- A QuickTime device driver for IIDC/DCAM type cameras such as the iSight.
- A network device driver supporting IP (Internet Protocol) over FireWire according to IEEE RFC 2734.
- Additional services for user-space and kernel access to all FireWire resources.

For information on writing FireWire drivers or applications, download the latest FireWire SDK from http://developer.apple.com/sdk/

Booting from a FireWire Device

The Power Mac G5 computer can boot from a FireWire storage device that implements SBP-2 (Serial Bus Protocol) with the RBC (reduced block commands) command set.

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For additional information about the FireWire interface and the Apple API for FireWire device control, see the references shown in FireWire Interface (page 67).

Target Disk Mode

The user has the option at boot time to put the computer into a mode of operation called Target Disk Mode (TDM). When the Power Mac G5 computer is in Target Disk Mode and connected to another Macintosh computer by a FireWire cable, the Power Mac G5 computer operates like a FireWire mass storage device with the SBP-2 (Serial Bus Protocol) standard. Target Disk Mode has two primary uses:

- high-speed data transfer between computers
- diagnosis and repair of a corrupted internal hard drive

The Power Mac G5 computer can operate in Target Disk Mode as long as the other computer has a 1394a or 1394b FireWire port and either any version of Mac OS X or Mac OS 9 with FireWire software version 2.3.3 or later.

To put the Power Mac G5 computer into Target Disk Mode, restart the computer and hold down the T key until the FireWire icon appears on the display. Then connect a FireWire cable from the Power Mac G5 to the other computer. When the other computer completes the FireWire connection, a hard disk icon appears on its desktop.

If you disconnect the FireWire cable or turn off the Power Mac G5 computer while in Target Disk Mode, an alert appears on the other computer.

To take the Power Mac G5 out of Target Disk Mode, drag the hard disk icon on the other computer to the trash, then press the power button on the Power Mac G5 computer.

Ethernet Port

The Power Mac G5 computer has a built-in Ethernet port that supports 10/100/1000 Mbps transfer rates. In operation, the actual speed of the link is auto-negotiated between the Ethernet PHY device that is internal to the K2 IC and the bridge, router, hub, switch, or other Mac or PC to which it is connected. The Ethernet port is auto-sensing and self-configuring to allow connection via either a cross-over or straight-through cable.

Both CAT 5 unshielded twisted pair (UTP) and shielded twisted pair (STP) cables work with the Ethernet port. An STP cable is recommended for noisy environments or run of greater than 100 meters.

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Note: When connecting a Power Mac G5 computer directly to another computer without using an Ethernet hub, a crossover cable is not required; circuits in the PHY detect the type of connection and switch the signal configuration as required.

The connector for the Ethernet port is an RJ-45 connector on the back of the computer. Table 3-4 (page 37) shows the signals and pin assignments for 10Base-T/UTP and 100Base-TX operation. Table 3-5 (page 37) shows the signals and pin assignments for 1000Base-T operation.

Table 3-4 Signals for 10Base-T/UTP and 100Base-TX operation

Pin	Signal name	Signal definition
1	TXP	Transmit (positive lead)
2	TXN	Transmit (negative lead)
3	RXP	Receive (positive lead)
4	–	Not used
5	–	Not used
6	RXN	Receive (negative lead)
7	–	Not used
8	–	Not used

Table 3-5 Signals for 1000Base-T Gigabit operation

Pin	Signal name	Signal definition
1	TRD+(0)	Transmit and receive data 0 (positive lead)
2	TRD–(0)	Transmit and receive data 0 (negative lead)
3	TRD+(1)	Transmit and receive data 1 (positive lead)
4	TRD+(2)	Transmit and receive data 2 (positive lead)
5	TRD–(2)	Transmit and receive data 2 (negative lead)
6	TRD–(1)	Transmit and receive data 1 (negative lead)
7	TRD+(3)	Transmit and receive data 3 (positive lead)

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Pin	Signal name	Signal definition
8	TRD–(3)	Transmit and receive data 3 (negative lead)

To interconnect two computers for 1000Base-T operation, you must use 4-pair cable (Category 5 or 6).

The Ethernet interface in the Power Mac G5 computer conforms to the ISO/IEC 802.3 specification, where applicable, and complies with IEEE specifications 802.3i (10Base-T/UTP), 802.3u-1995 (100Base-TX), and 802.3ab (1000Base-T).

Disk Drives

The Power Mac G5 computer has one 5.25 inch bay for optical drive access through the front panel and two 3.5 inch bays for internal hard disk drives. The optical drive is connected to the Ultra ATA/100 bus; the factory installed drive runs at 33 MHz. The standard configuration of the Power Mac G5 provides a 16x double-layer SuperDrive; a build-to-order Combo drive is available.

Hard Disk Drives

The enclosure has one drive carrier with two 3.5 inch bays for fixed-media mass storage devices. The drive carrier has data and power connectors for the both drives. The two drives on the independent Serial ATA buses implement revision one ports. Hard disk drive capacities are 160 GB and 250 GB with a 400 GB build-to-order option for some configurations. For references to SATA website information, refer to Serial ATA (page 67).

SCSI Drive

SCSI drives and SCSI PCI controller cards are available from third party providers. The Power Mac G5 computer supports external SCSI drives only.

SuperDrive

The Power Mac G5 computer has a tray-loading 16x SuperDrive (combination DVD+R double-layer, DVD+/-RW, and CD-RW drive). The SuperDrive can read and write DVD media and CD media, as shown in Table 3-6 (page 39).

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Table 3-6 Types of media read and written by the SuperDrive

Media type	Reading speed	Writing speed
DVD-R	8x (CAV max)	16x ZONE, 8x, 4x, 2x, 1x (CLV) depending on media
DVD+R	8x (CAV max)	16x/8x, 4x, 2.4x (CLV) single layer depending on media
DVD+R DL	6x (CAV max)	4x double-layer
DVD-ROM	16x DVD5 (CAV max) 8x DVD9 (CAV max)	–
DVD-RW	8x (CAV max)	6x, 4x, 2x, 1x (CLV) depending on media
DVD+RW	8x (CAV max)	8x, 4x, 2.4x (CLV) depending on media
CD-R	32x (CAV max)	24x (PCLV)
CD-RW	32x (CAV max)	24x (ZCLV) high speed CD-RW
CD-ROM	32x (CAV max)	–

The Apple SuperDrive writes to General Use media as follows: DVD-R 4.7 GB and DVD+R DL 8.5 GB. These discs are playable in most standard DVD players and computer DVD-ROM drives.

For compatibility information regarding recordable DVD formats, refer to

http://dvddemystified.com/dvdfaq.html#4.3

Digital audio signals from the SuperDrive can be played through the sound outputs under the control of the Sound Manager.

Combo Drive

As a build-to-order option, the Power Mac G5 computer can have a tray-loading combination DVD-ROM and CD-RW drive.

The Combo drive can read DVD media and read and write CD media, as shown in Table 3-7 (page 39).

Table 3-7 Types of media read and written by the Combo drive

Media type	Reading speed	Writing speed
DVD-ROM	12x DVD5 (CAV max) 8x DVD9 (CAV max)	–

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Media type	Reading speed	Writing speed
DVD+/-R	8x max (CAV)	_
DVD+R DL	4x max (CAV)	_
DVD+/-RW	8x (CAV max)	-
CD-R	32x (CAV max)	32x (ZCLV)
CD-RW	32x (CAV max)	10x (CLV, for high speed media)
CD-ROM	32x (CAV max)	–

Digital audio signals from the Combo drive can be played through the sound outputs under the control of the Sound Manager.

Internal Modem

The Power Mac G5 computer has an optional internal modem module. The external I/O connector for the modem is an RJ-11 connector installed on the rear panel of the computer. The modem has the following features:

- modem bit rates up to 56 Kbps, supporting V.90 and V.92 modem standards
- fax modem bit rates up to 14.4 Kbps

Depending on the configuration, the modem appears to the system as a USB device or I2S device that responds to standard AT commands. The modem provides a sound output for monitoring the progress of the modem connection.

AirPort Extreme Card

The Power Mac G5 computer supports the optional AirPort Extreme Card, an internal wireless LAN module. The AirPort Extreme Card is available as a build-to-order option or as a user-installable upgrade through the Apple Store.

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By communicating wirelessly with a base station, the AirPort Extreme Card can be used for Internet access, email access, and file exchange. A base station provides the connection to the Internet or the bridge between the wireless signals and a wired LAN or both. The AirPort Extreme Base Station has connectors for a wired LAN, a DSL or cable modem, and a standard telephone line using the built-in 56 Kbps modem that is available on some base stations.

When the AirPort Extreme option is included in the factory order, an external AirPort Extreme antenna is provided in the accessory kit and must be installed on the AirPort Extreme antenna port on the rear of the enclosure.

Complying with the IEEE 802.11g standard, AirPort Extreme transmits and receives data at rates up to 54 Mbps. Airport Extreme is also compatible with other devices that comply with the IEEE 802.11b standard, including PC's. For more information about Wi-Fi and compatibility, see the reference at Wireless Networks (page 68).

Note: As is the case with the existing IEEE 802.11b standard, actual data throughput will be lower than the indicated maximum connection speeds.

Data Security

AirPort Extreme has several features designed to maintain the security of the user's data:

- In 802.11b mode, the system uses direct-sequence spread-spectrum (DSSS) technology that uses a multi-bit spreading code that effectively scrambles the data for any receiver that lacks the corresponding code.
- The system can use an Access Control List of authentic network client ID values (wireless and MAC addresses) to verify each client's identity before granting access to the network.
- When communicating with a base station, AirPort Extreme uses 64-bit and 128-bit WEP encryption and WPA personal and enterprise modes to encode data while it is in transit. Additional security features may be available via software or firmware upgrades as 802.11 enhancements are ratified by IEEE.
- The AirPort Extreme Base Station can be configured to use NAT (Network Address Translation), protecting data from Internet hackers.
- The AirPort Extreme Base Station can authenticate users by their unique Ethernet IDs, preventing unauthorized computers from logging into your network. Network administrators can take advantage of RADIUS compatibility, used for authenticating users over a remote server. Smaller networks can offer the same security using a local look-up table located within the base station.

As an additional data security measure, VPN can be used in conjunction with the AirPort Extreme data security.

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AirPort Extreme Hardware

The AirPort Extreme Card is a wireless LAN module compliant with the IEEE 802.11g standard using both OFDM (orthogonal frequency-division multiplexing) and DSSS technologies. Using DSSS, AirPort Extreme is interoperable with PC-compatible wireless LANs that conform to the 802.11b standard at speeds of 11 Mbps, 5.5 Mbps, 2 Mbps, and 1 Mbps. Using OFDM, AirPort Extreme is compatible with all 802.11g standard speeds.

The AirPort Extreme wireless interface is on the PCI bus.

AirPort Extreme Software

Software that is provided with the AirPort Extreme Card includes:

- AirPort Extreme Setup Assistant, an easy-to-use program that guides users through the steps necessary to set up AirPort Extreme or set up an AirPort Extreme Base Station.
- Users can switch between wireless networks and can create and join peer-to-peer networks. These functions are accessed via the AirPort Extreme status menu.
- AirPort Extreme Admin Utility, a utility for advanced users and system administrators. With it the user can edit the administrative and advanced settings needed for some advanced configurations.

Bluetooth Technology

Bluetooth is an open specification that enables short-range wireless connections between desktop and laptop computers and a host of other peripheral devices. Bluetooth support is built into Mac OS X and compliant with Bluetooth specification 2.0 + EDR (enhanced data rate). It operates on a globally available 2.4 GHz frequency band (ISM band) for worldwide compatibility and has a maximum throughput of 3 Mbps. Bluetooth 2.0 + EDR is backwards-compatible with Bluetooth 1.x.

Bluetooth is available as a fully-integrated build-to-order option or as an Apple Authorized Service Provider kit, which can be installed by an Apple retail store or an Apple Authorized Service Provider. When the Bluetooth option is included on the factory order, the Bluetooth antenna is provided in the accessory kit and must be installed on the Bluetooth antenna port on the rear of the enclosure.

The Bluetooth technology supports the following profiles:

- serial port (SPP) —provides a wireless serial connection to other Bluetooth devices
- dial-up networking (DUN) — enables a mobile phone to act as a modem
- object push (OPP) —enables the transfer of files between Bluetooth devices
- human interface device (HID) — enables the use of Bluetooth input devices (keyboards and mice)

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- Bluetooth file transfer profile (FTP) — enables browsing of the file system of other Bluetooth devices which support Bluetooth FTP
- hardcopy cable replacement profiler (HCRP) — describes how to send rendered data over a Bluetooth link to a device, such as a printer. Although other profiles can be used for printing, the HCRP is specially designed to support hardcopy applications.
- headset profile (HSP) — enables the use of Bluetooth-enabled wireless headsets for applications such as iChat. This profile does not enable use of Apple Speech Recognition due to the fact that it is a low-precision audio channel.

For more information on Bluetooth technology, refer to Bluetooth (page 68).

Keyboard

The Power Mac G5 computer comes with an Apple Keyboard. It is a full-size keyboard with function keys and separate numeric keypad and editing sections.

The keyboard has an attached 1-meter cable and comes with a 1-meter extender cable for installations where the computer is located on the floor or away from the immediate desktop area.

Keyboard Features

Here is a list of the features of the Apple Keyboard.

- sloped design
- 109 keys (on the ANSI versions)
- 16 function keys
- 6 editing keys (Page Up, Page Down, Home, End, Forward Delete, and Help)
- USB HID Consumer Page Usage multimedia control keys
- full travel, standard pitch keys on alphanumeric, editing, and keypad sections, including function keys and cursor-position keys
- localized worldwide: 33 versions, standard layouts (including: ANSI, JIS, ISO)
- LED indicator on the Caps Lock key
- USB hub functionality with two USB 1.1 sockets

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Note: There is no power key on this keyboard.

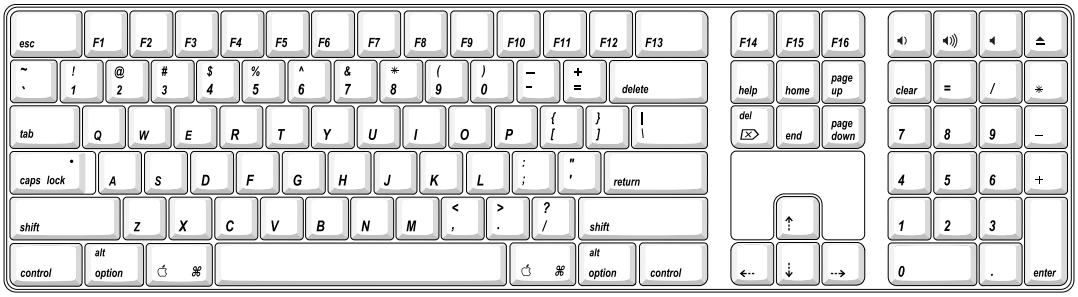
Keyboard Layout

There are localized versions of the Apple Keyboard for use in different parts of the world. The three standards used are ANSI (US and North America), JIS (Japan), and ISO (Europe).

Applications can determine which keyboard is connected by calling the Gestalt Manager and checking for the corresponding value of the `gestaltKeyboardType` selector.

Figure 3-4 (page 44) shows the keyboard layout for the ANSI keyboard.

Figure 3-4 ANSI keyboard layout



MultiMedia Control Keys

The keyboard has six multimedia keys: Volume Up, Volume Down, Mute, Brightness Up (F15), Brightness Down (F14), and Eject. Theses keys provide direct control of the features on the computer by way of the USB.

Keyboard and USB

The Apple Keyboard is designed to work with the computer by way of the USB ports. The keyboard has a captive cable with a USB Type A connector. The keyboard is a bus-powered USB hub with two USB Type A ports.

Warning: A bus-powered hub as defined in the USB specification does not provide enough power to support a second bus-powered hub. A second bus-powered hub must be connected to a USB port on the computer or other self-powered hub, not to a port on the keyboard.

Apple provides a HID class driver for the Apple Keyboard, which supports the USB boot protocol. Other keyboards intended for use on the Macintosh platform must support the HID boot protocol, as defined in the USB Device Class Definition for Human Interface Devices (HIDs).

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Programmer's Switches

Key combinations for programmer's switches that used the Power button on earlier models now use the Eject key. Here are the key combinations for the Power Mac G5 computer.

- Control-Command-Eject: restart immediately (reset)
- Control-Command-Option-Eject: shut down immediately
- Control-Eject: display the dialog for shutdown, restart, and sleep

The key combinations are decoded in software and may not be available under some crashed conditions.

NMI without Programmer's Switch

Current Macintosh computers do not have a programmer's switch, which allowed users to generate a non-maskable interrupt (NMI). The paragraphs below describe how to generate an NMI from a remote session for systems that do not have a physical programmer's switch.

Starting with Mac OS X 10.1.2, the OS will promote and recognize the `DB_NMI` bit in the "boot-args" property of the "chosen" node from Open Firmware. When the `DB_NMI` bit is set, the user can generate a non-maskable interrupt (NMI) by pressing the system's power button. This replaces the power button's sleep or wake response. The system reads the state of the bit at boot time from the `boot-args` configuration variable. For more information about the debug flags, please see *Inside Mac OS X: Kernel Programming* .

To set the `DB_NMI` bit, enter the following command at the Terminal to display the current debug flag settings.

```
% nvram boot-args
```

Add the parameter `debug=0x4`, as follows.

```
% sudo nvram boot-args="<current settings> debug=0x4"
```

After rebooting, press the power button for approximately 1 second to generate an NMI.

> **Note:** If the power button is pressed for more than five seconds, the system will immediately power off.

The power button will retain this functionality until Mac OS X is restarted without the `DB_NMI` bit set. To clear this bit, issue the `nvram` command omitting `debug=0x4` parameter, as follows.

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```
% sudo nvram boot-args=""
```

Note: The debug flags bit will be cleared if you use System Preferences to change the startup disk. It may also be cleared if you perform an installation that requires a restart.

Mouse

The Power Mac G5 computer comes with an Apple Mouse. The mouse case is made of polycarbonate plastic.

The Apple Mouse uses optical tracking in place of the traditional rolling ball. It works on almost any surface, though nonreflective, opaque surfaces without repetitive patterns work best.

Audio

The Power Mac G5 computer supports a sound system with both digital and analog audio. The new digital capability features Sony/Phillips Digital Interface (S/PDIF) input and output using optical connectors. S/PDIF technology results in a clean audio signal with no added noise to or from an external audio device.

Under the control of the system software, the sound circuitry digitally creates and records sounds. The Power Mac G5 computer can receive input only from either the analog input or the digital input. However, it can output simultaneously to digital and analog devices: the internal speaker, the headphone jack, the audio output jack, and the optical digital output connector.

By default, when components are plugged into the headphone jack or the rear line-out, the sound system mutes the internal speaker.

The headphones, rear line-out jack, and optical digital output are only muted when selected in the System Preferences. Muting and sound options are set in System Preferences:Sound:Output.

The analog and digital sound circuitries are not independent. Different audio streams cannot be played to the analog and digital circuitry. The selection of digital or analog output is performed through Sound pane in System Preferences.

The sound circuitry and audio device drivers handle audio data in multiple formats. Both digital and analog sound circuitry handle audio input and output data at sample rates of 32.0 kHz, 44.1 kHz, and 48.0 kHz at sample depths of 16 bits and 24 bits.

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If audio data sampled from another computer at a lower rate is played as output on the Power Mac G5, the Core Audio (Mac OS X's OS Level Audio API) transparently up-samples the data to the currently set sampling frequency prior to sending the audio data to the sound circuitry. To maximize audio fidelity, the Core Audio samples are stored as 32-bit floating point. The Sound Manager exists as a Carbon compatibility layer, but developers are encouraged to move their applications to Core Audio for maximum performance and fidelity, because the Sound Manager is capable of representing samples only as 16-bit values.

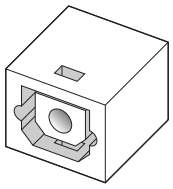
For more information about audio API's on Mac OS X, visit the Apple audio technologies developer web page at

http://developer.apple.com/audio/

Optical Digital Audio

Digital data is transmitted to and from the digital audio I/O using optical cables. The physical connectors, commonly referred to as TOSLink, are for both input and output and conform to IEC60874-17. The TOSLink friction-lock type F-05 connectors are available from pro-audio, musician's supply, hi-fi and other retailers. The 7.5 mm digital optical TOSLink input and output connectors, shown in Figure 3-5 (page 47), are located on the back of the enclosure.

Figure 3-5 Optical digital S/PDIF connector



The digital I/O circuitry can either perform input clock recovery on an incoming data stream or can sample using the internal clock. If samples are clocked using the internal clock, the data is run through the sample-rate converter on the digital circuitry. To enable bit-accurate copies, the external clock should be enabled in Audio MIDI Setup. Developers of applications that need this capability will need to provide access to the input clock recovery control.

Audio signals from the audio input jack are converted to digital data internally. All audio is handled digitally inside the computer, including audio data from the CD or DVD drive and from devices connected to the USB and FireWire ports. Audio data is converted to analog form for output to the internal speaker, the headphones, line output jacks, or external speakers.

For details on the optical digital input and output electrical specifications, refer to Optical Digital Input/Output Specifications (page 48).

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The Power Mac G5 computer also has the ability to lock its internal audio hardware to the incoming audio stream to synchronize the audio subsystem to an external device supplying the audio stream. This function allows audio and video to play in sync with the external audio or video device. The data format for signals transmitted over the optical cable is S/PDIF protocol IEC 60958-3.

The Power Mac G5 computer's audio subsystem has built-in sample-rate conversion (SRC) that allows the incoming audio to have a different rate than the playback audio, enabling the audio to come in the digital-in connector. For the best digital input quality in its purest form, set the audio clocking preference to "External Clock."

External Clocking

When the Power Mac G5 computer is set to "External" clocking, the computer audio circuitry will track and follow the incoming digital sampling rate and lock the internal audio hardware to the sampling rate of the external device. The external clock must be stable enough to be locked onto, otherwise the digital circuit will signal an error and the driver will fall back to using the internal clock.

Internal Clocking

When the Power Mac G5 computer is set for "Internal" clocking, the computer audio circuitry will run using the computer's internal clock. Incoming digital audio is automatically sample-rate converted to the selected output sample rate using the sample rate converter in the audio chip. The sample rate converter is high quality and does not use CPU bandwidth for audio conversion.

Optical Digital Input/Output Specifications

Based on playback of a 1 kHz, -1dBFS 24-bit sine wave playback, 24-bit 44.1 kHz output sample rate (unless otherwise specified below) the digital sound input and output have the following electrical characteristics (nominal specifications):

- Fsi – input sample rates (external clock mode): 32 kHz, 44.1 kHz or 48 kHz
- Fsi – input sample rate (internal clock mode): 16 kHz – 96 kHz
- bits per sample: 16-bit or 24-bit
- SNR (external clock mode): >130 dB
- SNR (internal clock mode, 16 kHz < Fsi < 96 kHz): >110 dB
- THD+N (external clock mode): < -130 dB (0.00003%)
- THD+N (internal clock mode, 16 kHz < Fsi < 96 kHz): < -110 dB (0.0003%)

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Audio Line-in

The Power Mac G5 has a stereo audio line-in jack on the back panel. The audio inputs are designed to accept high-level audio signals: 2 Vrms or +8 .2 dbu, which is the standard output level from CD and DVD players. The output level of some consumer audio devices is lower, often 0.316 Vrms or –10 dbV. Sound recordings made on the Power Mac G5 with such low-level devices have more noise than those made with high-level devices. The user may obtain better results by connecting an amplifier between the low-level device and the computer's audio input jack.

The audio input jack is a 3.5 mm miniature phone jack with the signals connected as follows:

Tip	Left-channel audio
Ring	Right-channel audio
Sleeve	Audio ground

Based on a 1 kHz, 2VRMS sine wave input, 24-bit 44.1 kHz input format, 0 db input gain and no weighting, the line input has the following electrical characteristics :

- maximum input voltage: 2 Vrms (+8.2 dBu)
- input impedance: > 47 kilohms
- bits per sample: 16-bit or 24-bit
- channel separation: greater than 75 dB
- frequency response: 20 Hz to 20 kHz, +0.5 dB/–3.0 dB
- THD+N distortion: below –78 dB (no weighting)

Audio Line-out

The Power Mac G5 has a stereo output jack on the back of the enclosure. The audio output jack is suitable for connecting amplified external speakers or other high input impedance (> 1K ohms) audio equipment.

The audio output jack is a 3.5 mm miniature phone jack with the signals connected as follows:

Tip	Left-channel audio
Ring	Right-channel audio
Sleeve	Audio ground

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Note: For best results, headphones or other low-impedance devices should not be plugged into the line-out jack. Such devices should be plugged into the front panel headphone jack.

Note: For best results, equipment plugged into the line-out jack should not connect the audio ground to other grounds, such as the chassis or "green wire" ground.

Based on a 1 kHz, -1 dBFS sine wave playback, 24-bit 44.1 kHz output format, -3 db output level and 100 kilohm load no weighting (unless otherwise specified below) , the line output has the following electrical characteristics (nominal specifications):

- output voltage (full-scale output): 1.4 Vrms (+5.1 dBu)
- output impedance: <50 ohms
- bits per sample: 16-bit or 24-bit
- channel separation: > 65 dB
- THD+N (total harmonic distortion plus noise): < –78dB (0.0125%) no weighting
- frequency response: 20 Hz to 20 kHz, +0.5 dB/–3.0 dB

Headphone Jack

The Power Mac G5 has a stereo headphone jack on the front of the enclosure. The headphone jack is suitable for connecting a standard pair of headphones. When a plug is inserted into the headphone jack, the internal speaker is muted.

The headphone jack is a 3.5 mm miniature phone jack with the signals connected as follows:

Tip	Left-channel audio
Ring	Right-channel audio
Sleeve	Audio ground

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Note: For best results, equipment plugged into the headphone jack should not connect the audio ground to other grounds, such as the chassis or "green wire" ground.

Based on a 1 kHz sine wave playback, 24-bit 44.1 kHz output format, -3 dB output level and 100 kilohm load no weighting (unless otherwise specified), the headphone output has the following electrical characteristics (nominal specifications):

- output voltage (full-scale output): 1.4 Vrms, (+5.1 dBu)
- output impedance: <50 ohms
- bits per sample: 16-bit or 24-bit
- channel separation: > 60 dB
- frequency response: 20 Hz to 20 kHz, +0.5 dB/–3.0 dB
- THD+N (total harmonic distortion plus noise): < –75dB (0.017%) no weighting

Video Monitor Ports

Table 3-8 provides the port definitions of the supported graphics cards.

Table 3-8 Supported Video Cards and Ports

Graphics IC	Port 1	Port 2
ATI Radeon 9600	single-link DVI TV out	single-link DVI
ATI Radeon 9650	single-link DVI TV out	dual-link DVI
NVIDIA GeForce 6800 Ultra DDL (build-to-order)	dual-link DVI TV out	dual-link DVI TV out

Single-link DVI ports support 23-inch Apple Cinema displays at 1920x1200. Dual-link DVI ports support 30-inch Apple Cinema HD displays at 2560x1600. All ports support a 32-bit resolution of 2048x1536 at 85 Hz.

The build-to-order GeForce 6800 Ultra DDL occupies both the AGP slot and the adjacent PCI slot. For information on PCI expansion, refer to PCI or PCI-X Expansion Slots (page 62). For information on video SDRAM and power, refer to Table 2-1 (page 28).

All of the graphics cards support dual displays in either extended desktop or video mirroring mode; for more detail, see Dual Display Extended and Mirror Modes (page 56).

The following sections describe the video connectors on the graphics cards.

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DVI Connector

The supported graphics cards have either one or two DVI-I (DVI with analog) connectors. With a DVI to ADC adapter, available separately and shown in Figure 3-6 (page 52), the DVI port on the Power Mac G5 computer can also support any Apple flat panel display that uses the flat panel connector.

Figure 3-6 DVI to ADC adapter

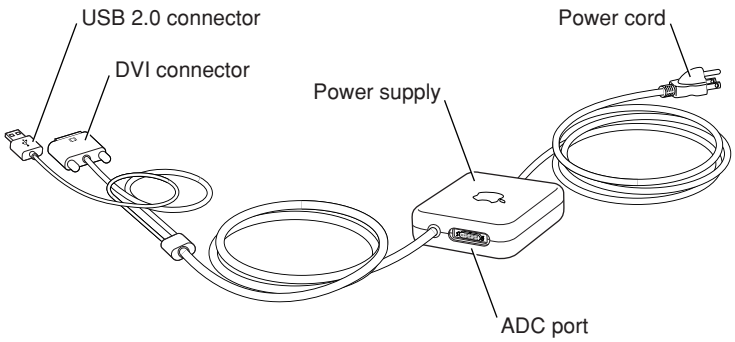

Figure 3-7 (page 52) shows the contact configuration for the DVI connector; Table 3-9 (page 52) lists the signals and pin assignments.

Figure 3-7 DVI connector

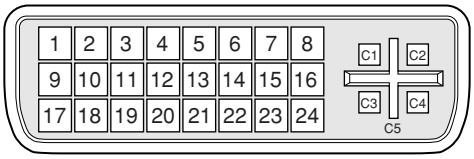

Table 3-9 Signals on the DVI connector

Pin	Signal name	Pin	Signal name
1	TMDS Data2–	13	TMDS Data3+
2	TMDS Data2+	14	+5V Power
3	TMDS Data2/4 Shield	15	Ground for +5V Power
4	TMDS Data4–	16	Hot Plug Detect
5	TMDS Data4+	17	TMDS Data0–
6	DDC Clock	18	TMDS Data0+
7	DDC Data	19	TMDS Data0/5 Shield

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Pin	Signal name	Pin	Signal name
8	Analog vertical sync	20	TMDS Data5–
9	TMDS Data1–	21	TMDS Data5+
10	TMDS Data1+	22	TMDS Clock Shield
11	TMDS Data1/3 Shield	23	TMDS Clock+
12	TMDS Data3–	24	TMDS Clock–
C1	Analog red	C4	Analog horizontal sync
C2	Analog green	C5	Analog ground (analog R, G, B return)
C3	Analog blue		

The graphics data sent to the digital monitor use transition minimized differential signaling (TMDS). TMDS uses an encoding algorithm to convert bytes of graphics data into characters that are transition-minimized to reduce EMI with copper cables and DC balanced for transmission over fiber optic cables. The TMDS algorithm also provides robust clock recovery for greater skew tolerance with longer cables or low-cost short cables.

For information about TMDS, see the reference listed in Digital Visual Interface (page 68).

Note: The Power Mac G5 computer includes a DVI to VGA adapter.

Apple Display Connector

The ADC connector on the adapter carries both digital and analog video signals as well as USB and control signals and power for an external monitor. Figure 3-8 (page 53) shows the contact configuration; Table 3-10 (page 54) and Table 3-11 (page 54) list the signals and pin assignments.

The maximum current available from the 25 V supply for the external monitor is 3.6 A.

Figure 3-8 Apple display connector

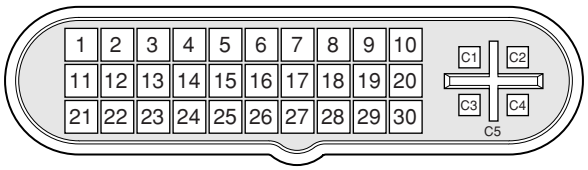

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Table 3-10 Digital signals on the Apple display connector

Pin	Signal name	Pin	Signal name
1	25 V Supply	16	TMDS Data1/3 Shield
2	25 V Supply	17	TMDS Data3–
3	LED	18	TMDS Data3+
4	TMDS Data0–	19	DDC CLock
5	TMDS Data0+	20	Clock Return
6	TMDS Data0/5 Shield	21	USB Data+
7	TMDS Data5–	22	USB Data–
8	TMDS Data5+	23	USB Return
9	DDC Data	24	TMDS Data2–
10	Vsync	25	TMDS Data2+
11	25 V Return	26	TMDS Data2/4 Shield
12	25 V Return	27	TMDS Data4–
13	Soft Power	28	TMDS Data4+
14	TMDS Data1–	29	Clock+
15	TMDS Data1+	30	Clock–

Table 3-11 Analog signals on the Apple display connector

Pin	Signal name
C1	Analog Blue Video
C2	Analog Green Video
C3	Analog Horizontal Sync
C4	Analog Red Video
C5	Analog RGB Return and DDC Return

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The graphics data sent to the digital monitor use transition minimized differential signaling (TMDS). TMDS uses an encoding algorithm to convert bytes of graphics data into characters that are transition-minimized to reduce EMI with copper cables and DC-balanced for transmission over fiber optic cables. The TMDS algorithm also provides robust clock recovery for greater skew tolerance with longer cables or low-cost short cables. For additional information about TMDS, see the references shown in Digital Visual Interface (page 68).

DVI to Video Adapter

The Power Mac G5 computer supports an optional DVI to S-video/composite adapter that provides S-video and composite output to a PAL or NTSC video monitor or VCR. When a display is connected by way of the video adapter, the computer detects the type of adapter and enables the composite and S-video outputs. The settings for the resolutions and standards (NTSC or PAL) are then selectable in the System Preferences Displays pane.

Note: The DVI to video adapter does not come packaged with the Power Mac G5 computer and must be purchased separately.

The video output connector is a 7-pin S-video connector. Figure 3-9 (page 55) shows the arrangement of the pins and Table 3-12 (page 55) shows the pin assignments on the composite out and S-video connector.

Figure 3-9 S-video connector

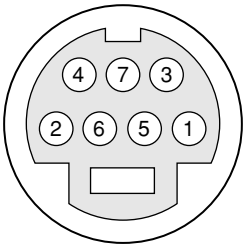

Table 3-12 Pin assignments for the S-video output connector

Pin number	S-video output connector
1	Analog GND
2	Analog GND
3	Video Y (luminance)
4	Video C (chroma)
5	composite video

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Pin number	S-video output connector
6	Unused
7	Unused

The Power Mac G5 computer provides video output at picture sizes and frame rates compatible with the NTSC and PAL standards; the picture sizes are listed in Table 3-13 (page 56). Those picture sizes produce under-scanned displays on standard monitors.

Table 3-13 Picture sizes for S-video output

Picture size	Pixel depth
800 by 600	24 bpp
832 by 624	24 bpp
1024 by 768	24 bpp

Dual Display Extended and Mirror Modes

The Power Mac G5 is equipped with two graphics ports. The Power Mac G5 can support dual displays in both extended desktop and video mirroring modes. Extended desktop mode lets users distribute work across two displays, increasing the amount of visible desktop space. Video mirroring mode displays the same information on both monitors, enabling the control of a presentation on one display, while allowing an audience to watch the presentation on a second display or projector. The NVIDIA GeForce 6800 Ultra DDL graphics card can power two Apple Cinema HD Displays.

To switch between extended desktop and video mirroring modes, enable the “Mirror Displays” option on the Arrangement tab in the Displays pane of System Preferences.

The scaling function is available when both monitors are operating and the mirror mode is selected. Either monitor could have black borders during mirroring, depending on the supported timings between the two displays and on the monitor’s selection algorithm. Both displays show full-sized images only when the resolutions match. Both displays can operate with other resolution settings, but in mirror mode, one of them has a display that is smaller than the full screen and has a black border around it.

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Expansion

This chapter describes the expansion features of the Power Mac G5 computer: the DDR SDRAM expansion slots and the PCI or PCI-X expansion slots.

Note: For detailed instructions on accessing the expansion slots, refer to the *Power Mac G5 Users Guide* that shipped with the computer.

RAM Expansion

The main logic board of the Power Mac G5 computer has 4 or 8 slots of DDR SDRAM expansion for unbuffered DDR400 (PC3200) dual in-line memory modules (DIMMs) for a maximum memory of 4 GB or 8 GB.

Each DIMM can contain 256 and 512 MB (and is capable of 128 MB or 1 GB) of double data rate synchronous dynamic RAM (DDR SDRAM). At least one pair of the RAM expansion slots contains factory installed DIMMs. The Power Mac G5 supports CAS latencies of 2, 2.5, 3, 4, and 5.

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Additional DIMMs must be installed in the slots in *pairs* of the same size. The slot pairs are numbered as indicated in Figure 4-1 (page 58) and Figure 4-2 (page 59). When installing additional memory, populate starting with the lowest slot pair numbers. The combined memory of all of the DIMMs installed is configured as a contiguous array of memory.

Figure 4-1 DIMM installation for dual 2.3 and 2.7 GHz processor configurations

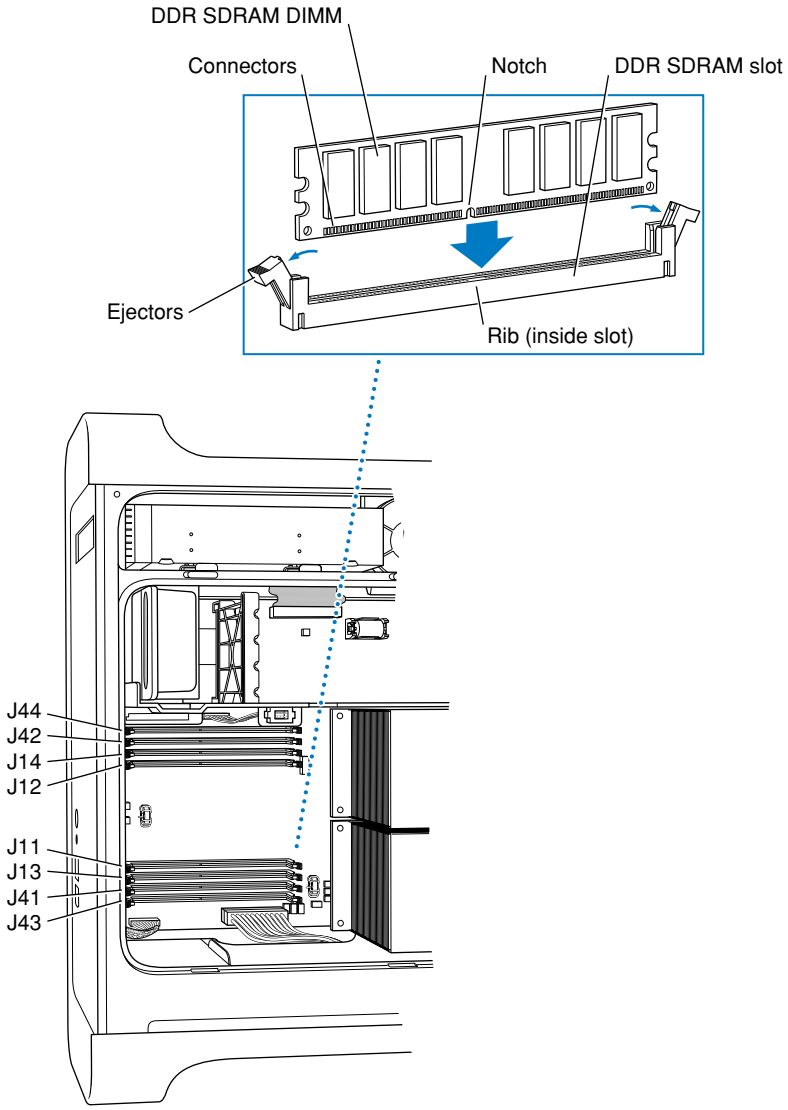

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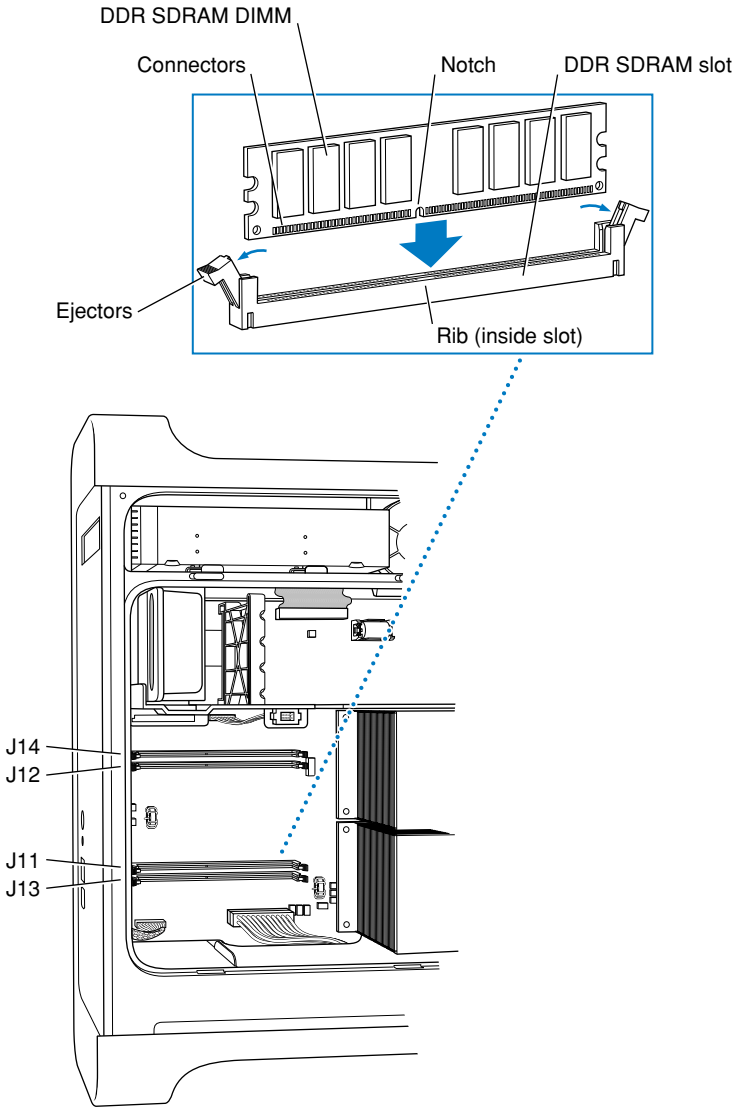
Figure 4-2 DIMM installation for dual 2.0 GHz processor configuration



DIMM Specifications

The RAM expansion slots accept 184-pin DDR SDRAM DIMMs that are 2.5 volt, unbuffered, 8-byte, nonparity, and DDR400-compliant (PC3200).

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Important: DDR333 (PC2700) or slower DIMMs do not work in the Power Mac G5 computer.

Important: DIMMs with any of the following features are not supported in the Power Mac G5 computer: registers or buffers, PLLs, ECC, parity, or EDO RAM.

Mechanical Specifications

The mechanical design of the DDR SDRAM DIMM is defined by the JEDEC specification JESD21-C, MODULES4_20_4, Release 11b. To find this specification on the World Wide Web, refer to RAM Expansion Modules (page 66).

The maximum height of DIMMs for use in the Power Mac G5 computer is 2 inches.

Electrical Specifications

The electrical design of the SDRAM DIMM is defined by the JEDEC specification JESD21-C, MODULES4_20_4, Release 11b. To find this specification on the World Wide Web, refer to RAM Expansion Modules (page 66).

The Serial Presence Detect (SPD) EEPROM specified in the JEDEC standard is required and must be set to properly define the DIMM configuration. The EEPROM is powered on 3.3 V. Details about the required values for each byte on the SPD EEPROM can be found on pages 68–70 of the JEDEC specification.

Important: For a DIMM to be recognized by the startup software, the SPD feature must be programmed properly to indicate the timing modes supported by the DIMM.

DIMM Configurations

The largest DIMM supported is a two-bank DIMM of 1 GB using 512 Mbit DDR SDRAM devices. The maximum number of devices per DIMM is 16.

Important: Power is delivered to the Power Mac G5 during sleep mode, so do not remove DIMMs while in sleep mode. A red light adjacent to the DIMM is illuminated when the duct door is removed and power is present.

Table 4-1 (page 61) shows information about the different sizes of DDR SDRAM devices used in the memory modules. The memory controller supports 64 Mbit, 128 Mbit, 256 Mbit, and 512 Mbit DDR SDRAM devices. The device configurations include three specifications: address range, word size, and number of banks. For example, a 1 M by 16 by 4 device addresses 1 M, stores 16 bits at a time, and has 4 banks.

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The first column in Table 4-1 (page 61) shows the memory size of the largest DIMM with that device size that the computer can accommodate. The third column specifies the number of devices needed to make up the 8-byte width of the data bus. The fourth column in the table shows the size of each bank of devices, which is based on the number of internal banks in each device and the number of devices per bank.

Table 4-1 Sizes of DDR SDRAM expansion DIMMS and devices

Size of DIMM	SDRAM device size	Device configuration	Devices per bank	Size of each bank
128 MB	128 Mbits	4 M x 8 x 4	8	64 MB
128 MB	256 Mbits	2 M x 16 x 4	4	64 MB
256 MB	128 Mbits	4 M x 8 x 4	8	128 MB
256 MB	256 Mbits	4 M x 16 x 4	4	128 MB
512 MB	256 Mbits	8 M x 8 x 4	8	256 MB
1 GB	512 Mbits	16 M x 8 x 4	8	512 MB

RAM Addressing

Signals A[0–12] on each SDRAM DIMM make up a 13-bit multiplexed address bus that can support several different sizes of SDRAM devices. Table 4-2 (page 61) shows the address multiplexing modes used with the devices.

Table 4-2 Address multiplexing modes for SDRAM devices

Device size	Device configuration	Size of row address	Size of column address
128 Mbits	4 M x 8 x 4	12	10
128 Mbits	2 M x 16 x 4	12	9
256 Mbits	8 M x 8 x 4	13	10
256 Mbits	4 M x 16 x 4	13	9
512 Mbits	8 M x 8 x 4	14	10

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PCI or PCI-X Expansion Slots

The following sections define the PCI and PCI expansion requirements.

PCI Only

Some configurations of the Power Mac G5 support three 64-bit 33 MHz PCI slots that interface to the K2 I/O. The PCI configuration conforms to the PCI Specification 2.3.

PCI-X Only

Some configurations of the Power Mac G5 support three PCI-X slots that interface to the HyperTransport bus via the PCI-X bridge. One slot runs at a maximum of 133 MHz and two slots run at a maximum of 100 MHz. The 133 MHz slot can support a maximum burst bandwidth of 1064 MBps, based on 64 bits times 133 MHz. The two 100 MHz slots can support a combined bandwidth of 800 MBps. It is recommended that the highest bandwidth card be inserted in the 133 MHz PCI-X slot labeled slot 4.

Note: Dual PCI-X card sets work best if installed in slots that are running on the same bus, i.e. the 100 MHz bus.

The PCI-X configuration conforms to the PCI-X Specification 10B.

PCI and PCI-X

To optimize performance of both PCI and main memory transfers, your PCI card should use DMA. The point-to-point G5 architecture is designed to provide optimal performance to each subsystem using DMA. If your card does not support DMA, it should use vector data types for read/write transfers. This approach results in 4 dword burst transfers on the PCI bus.

Important: The Power Mac G5 does not support marking memory space on PCI cards as cacheable. This technique was used in the past to improve read/write performance for cards without an on-board DMA engine. Cards using this technique will not function on the Power Mac G5.

The computer's case has four openings in the back for access to I/O connectors on cards in the three expansion slots and the AGP slot. Each slot has room for a full size 12.335-inch or short 6.926-inch card. The numbering on the casing is 1 through 4 and corresponds to the label on the PCB. Number one is the AGP slot and numbers two through four are the PCI or PCI-X slots.

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Note: The Power Mac G5's build-to-order NVIDIA GeForce 6800 Ultra DDL graphics card occupies both the AGP slot and the adjacent PCI slot. As a result, you can install PCI expansion cards in the slots labeled 3 and 4 but not in slot 2. To learn more about installing PCI cards, refer to in the *Power Mac G5 Users Guide* that came with your computer.

The expansion slots accept PCI or PCI-X cards with either 32-bit or 64-bit address and data buses. The expansion slots support universal and +3.3 V cards, but not 5 V signalling. The cards are required to use the standard PCI fence described in the specification.

Note: 5 V keyed or signalling cards do not work in the Power Mac G5 computer.

The expansion slots support all the required PCI signals and certain optional PCI signals. The PCI slots support the optional 64-bit bus extension signals and cache support signals.

The PCI slots and the AGP Pro 8x slot carry the 3.3 V_AUX power and PME signals to allow an expansion card to wake the computer from sleep mode.

A total of 90 W is allocated to the three PCI or PCI-X slots and the AGP Pro slot. Graphics cards that conform to the AGP 3.0 spec can consume up to 30W. AGP Pro cards may consume more power. AGP Pro cards may also block adjacent PCI or PCI-X slots, in order to provide thermal relief.

Warning: Before removing or installing PCI expansion cards, shut down the computer and unplug the AC power cord. The Power Mac G5 computer does not support PCI hot-plugging functionality. When the computer is powered-on or asleep, a red light on the main logic board is illuminated when the duct door is removed and power is present.

To install or remove a PCI or PCI-X expansion card: turn off power to the computer, unplug the computer, flip out the enclosure latch, open the side panel, remove the clear plastic air deflector, and remove the fan units. Remove the blank PCI fence for the appropriate slot, insert the card in the slot, and screw the card's fence into place to secure the card.

In order to use the new PCI or PCI-X card, a driver must be installed. The driver installation procedure is documented by the manufacturer of the PCI card.

For more information on PCI or PCI-X, visit the worldwide web at

http://www.pci-sig.org

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Supplemental Reference Documents

For more information about the technologies mentioned in this developer note, you may wish to consult some of the references listed in the following sections.

For information about older models of Macintosh computers, refer to the developer notes archive at

http://developer.apple.com/documentation/Hardware/hardware2.html

Apple Technical Notes

Apple Technical Notes answer many specific questions about the operation of Macintosh computers and the Mac OS. The notes are available on the Technical Note website at

http://developer.apple.com/technotes/

PowerPC G5 Microprocessor

Information about the PowerPC G5 microprocessor is available on the World Wide Web at

http://www-306.ibm.com/chips/techlib/techlib.nsf/techdocs/AE818B5D1DBB02EC87256DDE00007821

Velocity Engine

Velocity Engine is Apple's vector processor in the PowerPC G5 microprocessor. Apple provides support for developers who are starting to use the Velocity Engine in their applications. Documentation, development tools, and sample code are available on the Apple website, at

http://developer.apple.com/hardwaredrivers/ve/index.html

Motorola's implementation of Apple's Velocity Engine is named AltiVec. The *AltiVec Technology Programming Environments Manual* (AltiVec PEM) is a reference guide for programmers. It contains a description for each instruction and information to help in understanding how the instruction works. You can obtain a copy of the AltiVec PEM through the Motorola documentation site on the World Wide Web, at

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http://www.freescale.com/webapp/sps/site/overview.jsp?nodeId=02VS0l81285Nf2

3D Graphics

Developers of 3D graphics for games should know about OpenGL for Macintosh, a version of SGI's application programming interface (API) and software library for 3D graphics.

Developer support and documentation is available at

http://developer.apple.com/opengl/

Mac OS X

Initially, the Power Mac G5 computer ships with Mac OS X 10.4 installed as the default operating system. The classic environment can be used to run Mac OS 9 applications, For access to Apple's developer documentation for Mac OS X, see the Apple Developer Connection (ADC) website at

http://developer.apple.com/documentation/MacOSX/MacOSX.html

O'Reilly & Associates publishes a series of books about Mac OS X development. The books in this series have been technically reviewed by Apple engineers and are recommended by the Apple Developer Connection.

Open Firmware

The software architecture implemented on current Macintosh computers follows the standard defined by the Open Firmware IEEE 1274-1994 specification. Three Technotes provide an introduction to Open Firmware on the Macintosh platform. They are

TN 1061: *Open Firmware, Part I*, available on the Technote web site at

http://developer.apple.com/technotes/tn/tn1061.html

TN 1062: *Open Firmware, Part II*, at

http://developer.apple.com/technotes/tn/tn1062.html

TN 1044: *Open Firmware, Part III*, at

http://developer.apple.com/technotes/tn/tn1044.html

Other Technotes provide additional information about Open Firmware on the Macintosh.

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TN 2000: *PCI Expansion ROMs and You*, at

http://developer.apple.com/technotes/tn/tn2000.html

TN 2001: *Running Files from a Hard Drive in Open Firmware*, at

http://developer.apple.com/technotes/tn/tn2001.html

TN 2004: *Debugging Open Firmware Using Telnet*, at

http://developer.apple.com/technotes/tn/tn2004.html

RAM Expansion Modules

The Power Mac G5 computer uses DDR400 PC3200-compliant, 184-pin DDR SDRAM DIMMs.

The electrical and mechanical characteristics of the DIMM are given in JEDEC Standard 21-C. The specification can be found by using the search string JESD21-C on the Electronics Industry Association's website at

http://www.jedec.org/DOWNLOAD/default.cfm

ATA Devices

ATA (AT Attachment), also referred to as integrated drive electronics (IDE), is a standard interface used with storage devices such as hard disk drives. For more information on ATA, refer to the following Apple website at

http://developer.apple.com/documentation/Hardware/DeviceManagers/ata/ata.html

ATA Manager 4.0 supports driver software for internal IDE drives and includes DMA support. For the latest information about ATA Manager 4.0, see Technical Note TN1098, ATA Device Software Guide Additions and Corrections, available on the world wide web at

http://developer.apple.com/technotes/tn/tn1098.html

The web page for Technical Note TN1098 includes a link to a downloadable copy of *ATA Device Software Guide*.

Information about the ATA standards is available at the Technical Committee T13 AT Attachment website, at

http://www.t13.org/

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Ethernet

For information on Ethernet specifications and design guides, go to the World Wide Web at

http://standards.ieee.org/

Serial ATA

For information on Serial ATA specifications and design guides, go to the World Wide Web at

http://www.serialata.org

USB Interface

For more information about USB on the Macintosh computer, refer to Apple Computer's *Accessing Hardware from Applications* at

http://developer.apple.com/hardwaredrivers/usb/index.html

Mac OS X includes support for a wide variety of USB classes. Detailed specifications of these classes are available at

http://www.usb.org/developers/devclass/

For full specifications of the Universal Serial Bus, refer to the USB Implementation Forum on the World Wide Web, at

http://www.usb.org/developers/docs

FireWire Interface

For additional information about the FireWire IEEE 1394a and 1394b interfaces and the Apple API for FireWire software, refer to the resources available on the Apple FireWire website at

http://developer.apple.com/hardwaredrivers/firewire/index.html

The IEEE 1394a and 1394b standards are available from the IEEE; you can order these documents electronically from the IEEE Standards Department website at

http://shop.ieee.org/store

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You may also find useful information at the 1394 trade association's website at

http://www.1394ta.org/

Digital Visual Interface

For information about transition minimized differential signaling (TMDS) used with digital video monitors, see the specification, Digital Visual Interface DVI Revision 1.0, available on the website of the Digital Display Working Group (DDWG) at

http://www.ddwg.org/

Wireless Networks

More information about Wi-Fi and wireless networks using the IEEE 802.11 standard is available on the website of the WiFi Alliance, at

http://www.wi-fi.org

Bluetooth

For more information regarding Bluetooth technology, refer to the following locations on the World Wide Web.

Bluetooth specification:

http://www.bluetooth.org/spec/

Bluetooth SIG:

http://www.bluetooth.org

Bluetooth developer tools on the Apple web site at:

http://developer.apple.com/hardwaredrivers/bluetooth

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Conventions and Abbreviations

This developer note uses the following typographical conventions and abbreviations.

Typographical Conventions

Note: A note like this contains information that is of interest but is not essential for an understanding of the text.

Important: A note like this contains important information that you should read before proceeding.

Warning: A note like this contains a warning about a situation that could cause a system crash or loss of data.

Abbreviations

When unusual abbreviations appear in this developer note, the corresponding terms are also spelled out. Standard units of measure and other widely used abbreviations are not spelled out.

Here are the standard units of measure used in developer notes:

A	amperes	mA	milliamperes
dB	decibels	A	microamperes
Gb	gigabits	Mb	megabits
GB	gigabytes	MB	megabytes
Hz	hertz	MHz	megahertz
in	inches	mm	millimeters
k	1000	ms	milliseconds

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K	1024	s	microseconds
KB	kilobytes	ns	nanoseconds
kg	kilograms		ohms
kHz	kilohertz	sec	seconds
k	kilohms	V	volts
lb	pounds	W	watts

Other abbreviations used in developer notes include these:

ADC	Apple Display Connector
AGP	accelerated graphics port
ATA	advanced technology attachment
ATAPI	advanced technology attachment, packet interface
AV	audio visual
CAS	column address strobe
CAV	constant angular velocity
CD-ROM	compact disc read-only memory
CLV	constant linear velocity
DART	DMA Address Relocation Table
DB-DMA	descriptor-based direct memory access
DDC	display data channel
DDR	double data rate, a type of SDRAM where data is clocked on rising and falling clock edges
DIMM	dual inline memory module
DIN	Deutsche Industrie Norm
DMA	direct memory access
DRAM	dynamic random-access memory

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DVD	12 cm optical storage system with 4 GB capacity
DVD-ROM	DVD read-only memory
DVD-RAM	DVD that is both readable and writable
DVI	Digital Visual Interface
EDO	extended data out DRAM device type
EHCI	Enhanced Host Controller Interface, USB 2.0 specification
EIDE	extended IDE
EMI	electromagnetic interference
FCU	fan controller unit
G5	Generation 5, the fifth generation of PowerPC microprocessors, incorporating Velocity Engine technology
GART	Graphics Address Remapping Table
GBps	data throughput rate — giga bytes per second
Gbps	data throughput rate — giga bits per second
HID	human interface device, a class of USB devices
I2C	same as IIC
I2S	same as IIS
IC	integrated circuit
IDE	integrated device electronics
IEEE	Institute of Electrical and Electronics Engineers
IEEE 1275	the official specification for Open Firmware
IEEE 1394a	the official specification for FireWire 400 (400 Mbps)
IEEE 1394b	the official specification for FireWire 800 (800 Mbps)
IIC	inter-IC (an internal control bus)
IIS	inter-IC sound bus
I/O	input/output

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ISO	International Organization for Standardization
JEDEC	Joint Electronics Devices Engineering Council
K2	I/O device and disk controller
L2	level 2 (refers to level of cache)
L3	level 3 (refers to level of cache)
LAN	local area network
MAC	media access controller
Mac OS	Macintosh Operating System
MBps	data throughput rate — mega bytes per second
Mbps	data throughput rate — mega bits per second
OFDM	orthogonal frequency-division multiplexing
OHCI	Open Host Controller Interface, USB 1.1 specification
PCI	Peripheral Component Interconnect
PHY	physical layer
PIO	programmed input/output
PMU	power management unit
RADIUS	Remote Authentication Dial-In User Service
RAM	random-access memory
RAS	row address strobe
RBC	reduced block commands
RGB	a video signal format with separate red, green, and blue components
RISC	reduced instruction set computing
RMS	root mean square
ROM	read-only memory
SATA	serial ATA bus for hard disk drives

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SBP	Serial Bus Protocol
SPD	Serial Presence Detect
SPU	service processor unit
SCSI	Small Computer System Interface
SCC	serial communications controller
SDR	single data rate
SDRAM	synchronous dynamic random access memory
SO-DIMM	small outline - dual inline memory module
SRAM	static random access memory
U3H	memory controller heavy version
USB	Universal Serial Bus
TMDS	transition minimized differential signaling
VESA	Video Electronics Standards Association
VRAM	video RAM; used for display buffers
Wi-Fi	Wireless Fidelity. Used by the Wireless Ethernet Compatibility Alliance for certification of interoperability of 802.11 products

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